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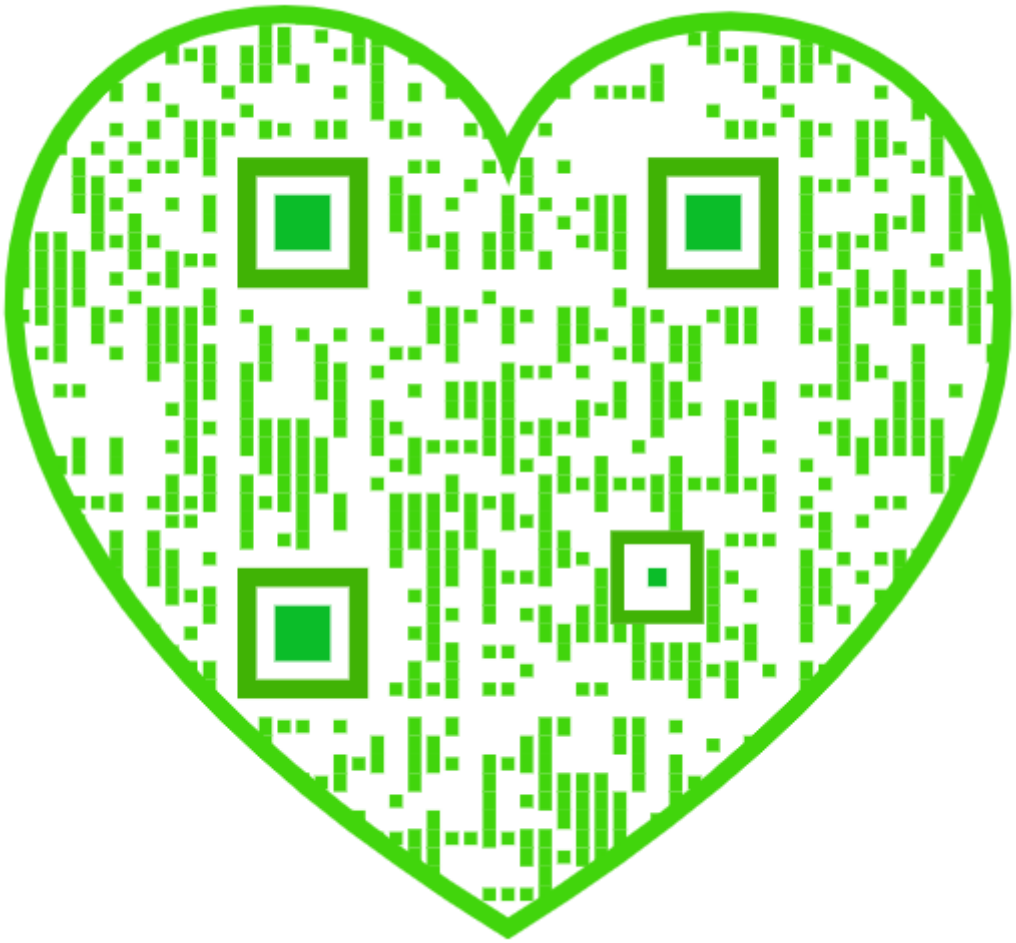

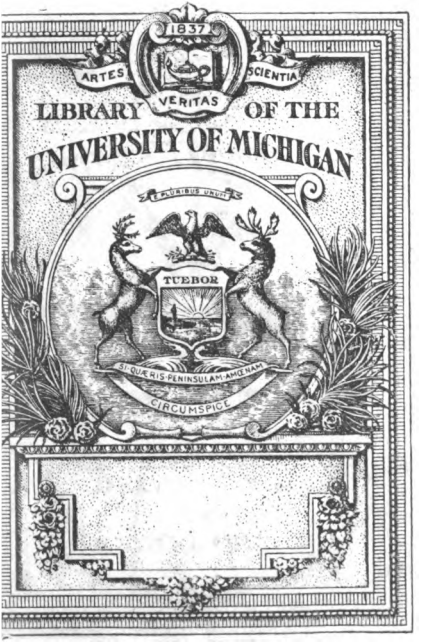

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HISTORICAL & DESCRIPTIVE Anecdotes. OF STEAM ENGINES, AND OF THEIR INVENTORS & IMPROVERS.

BY

Robert Stuart Esq.
Civil Engineer.

VOLUME SECOND.

London,
Wightman & Comp.
1829.

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Mickleham, Robert.

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VOLUME II.

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VOLUME SECOND.

CHAPTER SIXTEENTH.

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"BY THE FALL OF DROPS OF WATER, BY DEGREES, A POT IS FILLED.—*Proverbs.*

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CHAPTER SIXTEENTH.

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"BY THE FALL OF DROPS OF WATER, BY DEGREES, A POT IS FILLED."—*Proverbs.*

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THE sole right to manufacture and use the condensing engine, having been given by Parliament, for a very long period, to its meritorious inventor, considerable rivalry was raised up among mechanics to adapt the common engines to manufacturing as well as to mining purposes. For, in addition to the prejudices which Watt's mechanism had to encounter on the score of its complexity, his apparatus was costly, and not easily kept in repair. There were many who would not see the ultimate saving of this expense in a great present saving of fuel, and others who protested they could not. Among the latter, may be reckoned Mr. Matthew Wasbrough, an ingenious mechanic, who, in conjunction with his father, carried on an extensive brass foundery in Bristol, and in 1779 invented a means of connecting the balanced lever-beam with the pistons, so as to produce a rotary motion.

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In the description deposited in Chancery, he says that he accomplished this by one or more pulleys or wheels, or segments of wheels, to which were fastened ratchets or checks. In another case, he shifted a wheel and its axis from one set of teeth to another; a third method was employing racks with teeth, which tumbled or moved on their own axis or centre, and those racks he fastened to the working beam or great lever, or they were connected with it by means of chains or spears. For other purposes, instead of a working beam he substituted a wheel or pulley, working by racks or chains from the steam piston; and to regulate the motion, he, in some cases, added a fly. This is also the second example of a patent being taken out for the application of steam-engines to propel boats.

During the erection of one of his rotular mechanisms at Birmingham, Mr. John Pickard, for whom it was constructing, made a great simplification of the apparatus; and which he secured by a patent.

A crank was placed upon the axis, which was to transmit the motion from the atmospheric engine to the machinery, which was connected by an inflexible rod to one end of the working beam. A wheel was also placed on the axis, having a heavy weight placed on one part of its circumference, so that when the crank was in the line of the connecting rod, or in the position in which it was incapable of receiving any impulse from the working beam, the weight on the wheel should impel it onwards by its acquired momentum, until the crank had passed its neutral point. By fixing this loaded wheel on a second axis, and making its diameter half of the wheel placed on the crank axis which moved it, it made two revolutions

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while the crank made one, and thus improved its action as a regulator of the engine.

There was no difference in the use of this loaded wheel from that of the fly proposed by Wasbrough; but getting rid of the ratchet-wheels in his rotular movement, and substituting the crank in its place, was a very great step in improvement, and which could be applied as well to the condensing as to the atmospheric engine to make either produce a rotary motion from a rectilineal alternating one.

Wasbrough and Pickard became associated as partners in the benefits arising from their combined contrivances, and as these were, at the time considered to be inventions of great importance, Wasbrough quickly had many opportunities of introducing the mechanism into practice; particularly in some of the woollen manufactories in Gloucestershire, and, among others, in the establishment of Mr. Ansty. But the place in which it was seen to greatest advantage, was in its application to turning lathes in the works erected by Mr. John Taylor* at

* The elder Mr. TAYLOR spent some years of his life at sea, and had thus many opportunities of witnessing the danger occasioned by the defective make of the blocks, shivers, and pins, at that time used in the rigging of vessels. There was a want of precision in every part of their construction, that frequently rendered them unserviceable at the very moment when the safety of the vessel depended on the readiness of their movements. On his return from sea, in conjunction with his son, he applied himself to the invention of machines, which, though worked only by hand, formed blocks, shivers, and pins, on a principle that gave them a decided superiority over all those that had been previously constructed. The cellar in Southampton in which he made these experiments was often visited by the Duke of York, brother to George III., and others, to witness his ingenious operations. And here he was the object of much vulgar ridicule, and was said to be employed in "raising the devil." When he was a pri-

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Southampton, to manufacture ships-blocks, and in which Wasbrough was also concerned generally as an engineer.

soner of war in France, in 1746, he constructed an electrical machine for some friars at Rouen, in Normandy. On his return to Southampton, he formed another, with which he exhibited experiments; this was sold for one hundred pounds to a person who afterwards travelled with it. His health became impaired by much confinement in the unwholesome place in which he made his experiments, and he died in 1762. His son, WALTER TAYLOR, fortunately succeeded in introducing the invention into the navy, and the contract which government entered into with him for supplying them, enabled him to clear the embarrassments which had been accumulating from the commencement of his father's and his own experiments, and at one time threatened altogether to overwhelm him. In the prosecution of his manufacture, he invented *circular saws*, by which the thinnest shivers of the hardest lignum vitæ could be cut with expedition and precision. Also the shells and mortices of the blocks, which formerly were only to be done by tedious manual labour, with the axe, the mallet, and the chisel. Metal, peculiar in its temper, was formed so as to resist the injuries of time, wear, and weather, longer than any before discovered. He greatly improved the hand-pump used on board ships, by introducing a pendulum instead of a valve. The trials he made with this led him to the invention of a method by which a ship could be easily cleared of water at the rate of four tons in two minutes and a half. This wheel he called a *double bailing machine*, and obviated a great defect which remained in ships' pumps, of drawing the water from a depth at one time thirty-two feet when the weather is clear, and when foul not more than twenty-eight feet, or when full manned and the atmosphere loses its spring so as not to support a column higher than twenty-six feet. His death, in 1803, at the age of 69 years, left a deep impression of regret among the poor, who experienced his generous bounty; and among those who delighted to trace the operation of christian principles in his diffusive good-will, and in his sympathy for the afflictions of the distressed and wretched. His hospitable abode was open to good men of every persuasion; and there the zealous Romaine, and the benevolent Newton, the friend of the poet Cowper, who were often his summer guests, sunk every inferior prejudice in the expanded pleasure of christian friendship.

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Subsequently to his adapting his movement to this purpose, he was employed by government to erect a steam-engine at the Red-house, Deptford, to give motion to the mills for grinding and dressing corn for the navy; and he was desired by the Commissioners of the Victualling Board to consider and let them know, whether "the great improvements in steam-engines, said to have been made by Bolton and Watt, could be adopted in the one he was to erect at Deptford." His reply (March, 1781) contains a summary of the objections which at that time may be considered as the strongest that could be urged against the condensing engine. He had originally thought of applying his rotary movement to Bolton and Watt's machine, but he had changed his intention. "I will briefly," says he, "mention to you, Honourable Sirs, the principle of each engine of the common sort; the steam filling in the cylinder the place of air, (being a medium easily reduced) is condensed by cold water, which making a vacuum, the impulse downwards is occasioned by the unresisted pressure of the atmosphere, which would continue acting upon the upper surface of the piston, so as to keep it down; but in the action, when nearly at the bottom of the cylinder, the machine itself shuts the water (or injection cock) out and lets in the steam, which restoring the equilibrium in the cylinder, and having at all times on the exterior end of the working beam a weight sufficient to bring it up again to its original state of rest, where likewise it would remain, but that the machine in its action upwards shuts out the steam as at first. Now in Bolton and Watt's engine they do not condense in the cylinder, but press the steam through the pipes into a vacuum condenser. The effect is the same, but the im-

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pulse is at all times equal to the pressure of the steam (not atmosphere) on the upper surface of the piston; from which you will please to observe, one is acted upon by the *uniform* pressure of the atmosphere (and in the return of the stroke by gravitation), and the other is acted upon by the *fluctuating* elasticity of the steam, which is continually varying with the strength of the fire; which requires a great deal more care than servants generally take, or the machine will have nearly the effects of a wind-mill, sometimes very slow, the fire being weak, and sometimes unmanageably fast, the fire being strong; besides they are very costly, complex, and very difficult to be understoood, so that when out of order they cannot (as the others) be repaired by a common smith or millwright." From this letter, it appears that a condensing engine was in action at Stratford, near London, and another at the waterworks at Chelsea. Wasbrough had made considerable progress in the construction of this machine, when Bolton made his appearance as a competitor for the patronage of the Navy Board, and eventually succeeded in having his new engine substituted instead of Newcomen's; he induced Wasbrough to make a joint proposal with him to erect an engine at the Red-house, combining all the improvements of both; and the offer was accepted by the Commissioners of the Victualling Office. While Wasbrough was waiting for Bolton's directions respecting his peculiar part of the apparatus, he received intelligence that Mr. Smeaton had received instructions to erect an engine to throw water on a water-wheel for grinding corn at the Red-house, and that this was to supersede his mechanism. "Surely," says he, in a letter to the Navy Board, "Mr. Smeaton or any

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other mechanist, does not propose this as a better mode than mine, indeed if he did, you must be convinced to the contrary, after knowing that my method has been in practice many years; and after hearing Mr. Bolton's pretended claim to this invention, which proves that he knows its singular advantages. When I last attended your honourable board, you were pleased to speak in the warmest terms of my whole conduct respecting this matter. If you had not then been satisfied with the proofs which were laid before you, I should have been happy in conducing further to that end, before I gave out to my friends, and those whose business required such a mechanical force, that I had your approbation and orders to proceed. This is not the greatest part of the bad consequences that attend it. It was not the value of the premium that induced me, for I had rather have given you that, and even the engine, than thus have a negative passed on my machine by so respectable a body of gentlemen in their public capacity. Those who have promised me orders, on condition that this answers the purpose, will now no doubt withdraw them, and the probable consequences of your decision may be a loss of several thousands to me. Had this circumstance entered your minds, I am well convinced your humanity would have made you pause, at least till you were better satisfied than with the word of any interested individual, before you adopted a plan so opposite to that you had so lately approved of." The Commissioners assured Wasbrough, that his surmises, as to Smeaton, were without foundation; but their reply left him no encouragement to hope that his mechanism would be adopted. This disappointment, coming upon him at a time when he was in a state of

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precarious health, and acting on a mind of extreme sensibility, hastened the progress of his disorder. At his death his patent was divided into shares, and many machines were afterwards fitted with his peculiar contrivance *.

Wasbrough's friend had given true information. Notwithstanding the evasion of the Commissioners, that they had not instructed Smeaton, or any one else, to *erect* an engine and water-wheel at Deptford, they had employed him (after entering into a contract with Bolton and himself) to give his opinion and design of the best mode of constructing this flour mill and impelling it by a steam-engine. Smeaton's report is in itself a curiosity. He was the friend and correspondent of Bolton and of Watt: he admired their condensing engine. He was warm at all times, and in all places, in his recommendations to adopt it in preference even to his own improved atmospheric-engine; but both the one and the other were, in his opinion, unfit to be used directly as the mover of a corn-mill. "I apprehend," says he, "that *no motion* communicated from the reciprocating lever of a fire-engine *can ever produce a*

* Mr. Matthew Wasbrough was born at Bristol in 1753. As the best evidence of the estimation in which he was held by his townsmen, we quote the record of his death, in his twenty-eighth year, from the *Bristol Gazette* of 1781.

"Sunday, October 21, Died, sincerely regretted by his friends and acquaintance, Mr. Matthew Wasbrough. The public have to deplore in him the loss of one of the first mechanics in the kingdom, whose early genius brought to perfection that long-wished-for desideratum, the applying the steam-engine to rotular movements: upon this principle, he lived long enough to complete several ingenious and complete pieces of mechanism, in which the corn and flour-mills, in Lievens Mead, are striking monuments of his extensive abilities; his name, therefore, will be handed down with honour to posterity."

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perfect circular motion, like the regular efflux of water in turning a water-wheel. All the fire-engines that I have seen are liable to sudden stoppages, and may, in the course of a single stroke, pass from almost the full power and motion, to a total cessation; for whenever, by inattention of the engine-keeper, the elasticity of the steam becomes too low, the engine will be incapable of continuing its motion. The fire-engine seems peculiarly adapted for raising water, and then a stoppage for a few strokes is only a loss of so much time; but such stoppages in the motion of millstones for grinding corn would greatly confuse the regular operation of the mill, as it would stop with the stones full charged with corn, and before the motion could be renewed the stones must be raised up from their bearings. By the intervention (he continues) of a water-wheel, these uncertainties and difficulties are avoided, for the work is, in fact, a water mill, and if there is a sufficiency of water in the reservoir to work the mill one minute, without sensible abatement, it will seldom happen but that the engine may be set a-going again in less than half a minute after it stops by any common accident, so that the mill will continue regularly at work."

No one was more sensible than Watt, that until some scheme was devised for producing a rotary motion, from a reciprocating one, he had made but a comparatively small progress in making his condensing engine available for any use but that of a drawer of water. "Among the many schemes," says he, "which passed through my mind, none appeared so likely to answer the purpose as an application of a crank, in the manner of a common turning-lathe (an invention of great merit, of which the humble inventor, and even its

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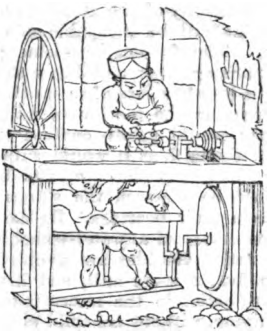
era are unknown); but as the rotative motion is produced in that machine by the impulse given to the crank, in the descent of the foot only, and is continued in its ascent by the acquired momentum of the wheel, which here acts as a fly, and



being unwilling to load my engine with a fly heavy enough to continue the motion during the ascent of the piston, and even where a counter-weight employed to act during that ascent of a fly heavy enough to equalize the motion, I employ two engines, acting on two cranks, by which means a motion might be rendered nearly equal, and a very light fly would only be requisite."

His attention being at that time chiefly directed to erecting engines for raising water, the trial of his idea was postponed, and he did not attempt to put them into practice until about 1778 or 1779, when he says, his attention was drawn to the

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failure* of a mechanism similar to Fitzgerald's, for which a Mr. Wasbrough, at Bristol, had obtained a patent. This model exceeded his expectations; but having neglected to take out a patent, the invention was communicated by a workman, employed to make the model to some of the people about Wasbrough's engine. The fact, continues Watt, was confessed by the opposite party; but he alleged it had occurred to himself previous to his ever hearing of mine, which might be a fact, as the application of it to a single crank was sufficiently obvious; and in these circumstances he thought it better to accomplish the same end by other means than to enter into litigation, and by demolishing the patent (Pickard's) to lay the matter open to everybody." Subsequently, it has been stated †, that he used the crank when it suited his purpose, in defiance of the patentee, who never molested him.

The rivalry that so simple and obvious a contrivance called forth, and the great importance that was attached to its exclusive possession, is one of the many curious illustrations afforded in the progress of this machine of the great value of even apparently trifling improvement. Watt mentions the turning-lathe as suggesting the idea to his mind; but at the moment, another elegant application of the same contrivance was to be found in most farm-houses in the country, and the common

* This is probably a misconception; "for, so far from the engine of Wasbrough being irregular, or defective, it continued in action thirty years, when it was destroyed by fire; with no other than casual repairs, and without any alteration whatever in its mechanism."

† *Supplement, Ency. Brit.* vol. vi., art. WATT.

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wheel for spinning flax was familiar to almost every one from their infancy. All the mechanical books, from Besson downwards, abound in contrivances for this purpose; mills for grinding corn were turned by a lever having a reciprocating motion, and a vertical alternating movement was given to saws, from the continuous action of a water-wheel, and the saws themselves were kept in a vertical, rectilinear direction by their frames moving in an inflexible groove; and, in fact, this identical arrangement has been lately introduced into machines of great elegance of form and arrangement; but they were overlooked by those who were in search of them, and who rested satisfied with far less perfect contrivances.

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CHAPTER SEVENTEENTH.

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"HE WHO HAS LAID UP NO MATERIALS CAN PRODUCE NO COMBINATIONS, FOR INVENTION IS BUT THE POWER OF ARRANGING IDEAS SELECTED FROM THE STORES OF REMEMBRANCE."—*Hawkesworth.*

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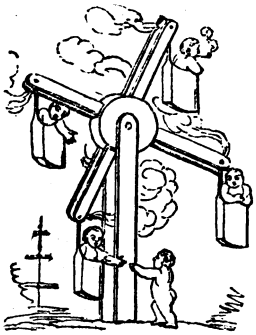

ALL the machines which Watt had constructed, being employed to raise water, the interval during which the impulse of the steam was suspended, while the counterweight drew the piston to the top of the cylinder, if not necessary, was at least not detrimental to the perfect action of the pumping apparatus. But when it was attempted to apply the same engine to move machinery requiring a steady rotary movement, the inactive or returning stroke of the piston was as hurtful as it was inconvenient.

Some of these disadvantages, it was thought, might be obviated by making the steam act on a piston, which moved in a circular, instead of a rectilineal path. With this view Watt suggested the contrivance shown in the engraving (marked WATT Q., fig. 2.); *a*, is a portion of a cylinder, or drum, shut at both ends; *b*, an axis; and *c*, a piston fixed upon it, which moves within the cylinder so as to be steam tight; *d*, a valve moving

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on a joint at *e*, and made to press against the circumference of the axis; *f*, a pipe, conducting steam from the boiler into the drum; and *g*, a pipe connecting the drum with a condenser. When these parts are placed as shown in the figure, steam will issue from the boiler and fill the space between *c* and *d*, and the rest of the cylinder will be open to the condenser. As the valve, *d*, which acts as an abutment, presses against the axis, *b*, the piston, *c*, is carried round until it comes near the point, *e*, when the injection and steam pipes, *e*, *f*, are closed by valves (which are not shown in the figure), and the abutment valve, *d*, is made to fall into the recess, *h*, by means of a wheel or lever on the outside of the drum. The momentum of a fly-wheel placed on the axis, *b*, carries the piston, *c*, over this recess; the valve, *d*, is then again moved from its seat into its former position, and at the same time the injection and steam valves are opened; a vacuum is thus produced throughout the cylinder, except in the space between *c* and *d*, and the elasticity of the vapour which flows into it carries the piston round as before. It will be seen that from a wheel placed on the outside of the drum the rotary motion may be communicated to other machinery.

The valves which were omitted in the figure 2 will be understood from an inspection of figures 1 and 4, which represent what Watt called his semirotary engine, in which a piston moving in a circular channel, produced an alternating movement. In this a vacuum is made alternately on both sides of the piston *c*, and steam from the boiler acts also alternately on the same surfaces. In figure 1 the mechanism is represented as if the piston had finished one stroke, and was at the

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commencement of another. The steam now flows through the pipe *m* into the box *t*, and thence through the valve *x* into the drum *a*: the valve *l* being open, the drum has a communication through it with the condenser, and the steam through *n* presses the piston *c* round, until it is near the point *w*: the condenser valve *l*, and the steam-valve *k* are then shut; the other valve *n*, communicating with the condenser, and also the steam-valve *i* are opened; the steam then acts on the opposite side of the piston, and the inside of the drum communicates with the condenser, through the valve *n* in the pipe *f*: the piston is then impelled into its first position, and so on alternately. The projecting box *o* contains a steam-tight stuffing. The alternate revolving motion is communicated to the pumps by a wheel *p*, (figures 3 and 4), fixed on the axis *b*, and working into racks on the pump rods *r*, *u*. The same letters in all the figures refer to the same parts.

Another rotary motion was produced directly from the action of the steam by a mechanism shown in the engraving, marked WATT R.:—*a*, is a circular vessel, moving on pivots, *r*, *s*, divided into two compartments, *k*, *l*, by the division, *b*; *c* and *d*, are valves opening inwards, and *e*, *f*, valves opening outwards; *g*, a pipe connecting each of the divisions, *k*, *l*, in succession, with a condenser, *m*; pipe, *n*, supplies steam from the boiler alternately to each division or chamber, so that when the chamber, *k*, is open to the condenser, the chamber, *l*, is open to the boiler: this circular vessel is enclosed in a box, *o*, *p*, filled with water or some other fluid.

If now a vacuum were made in both of the chambers, the water would rise through the valves, *c* and *d*, and fill them; and as long as the division,

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k, opens into the condenser, it will remain filled with the fluid; but *l*, being open to the boiler, the steam presses the water which it contains through the valve, and this re-acting on the water in the box, imparts a rotary motion to the circular vessel; and when the chamber, *l*, has moved so far round as to be in the position of *k* in the figure, it will be filled with the steam which has expelled the water, and will also communicate with the condenser: a vacuum will thus be speedily produced in it, and the water in the box will lift the valve *d*, and flow upwards until it fills it; while the pressure of the water will shut the valve, *f*, through which it had issued. At the moment when the chamber *l* communicated with the condenser, the chamber *k*, which was filled with water, was opened to the boiler, and the steam from the pipe *n*, pressed the water through the valve *e*, and its re-action on that in the box continued the rotary movement until the chamber *l*, which was now again filled with water, was in the position shewn in the figures. All these machines on trial were found defective. In the first scheme the abutment valve was soon put out of order, and the passage of the piston over the openings to the condenser and boiler, quickly destroyed the tightness of the stuffing of the piston. The semirotary engine, although ingenious, was inferior to his common condensing engine, with a vibrating lever-beam. The re-action of the water, issuing from the revolving vessel on the fluid in the box, was found to impart a force, altogether of trifling amount.

What he failed in accomplishing by these contrivances, he succeeded in obtaining by another method. By a very slight alteration of the three valves of his mechanism, and the introduction of a fourth, Watt produced a new combination of the parts

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of his machine, by which all the practical difficulties that had baffled his predecessors were removed. The scheme he had already explained and described by a drawing, which he exhibited to the House of Commons at the time when he presented his petition for a prolongation of the term of his patent. In that drawing, he showed that after the piston had been pressed by the steam to the bottom of the cylinder, by shutting off the connexion between the upper part and the boiler, and opening a communication between it and the underside of the cylinder, the steam by this means could be made to *raise* as well as *depress* the piston, into a vacuous space which might be maed above and below it alternately. By this beautiful extension of his first idea it may be considered as having been perfected, and the mechanism could now be freed from the dead weight of counterpoises, with which it had been encumbered and loaded ever since the attempts of Newcomen.

The engraving marked WATT, R., figures 1 and 11, are sections of the cylinder, and figure 8 an end view; which will explain the placing of the valves and pipes, for connecting the upper and under side of the cylinder with the condenser and boiler: *a*, the piston; *b*, the steam-pipe; *c*, valve admitting steam above the piston; *d*, valve for admitting it beneath; *e*, valve connecting upper side of cylinder with the condenser; *f*, a similar valve, opening the lower part to the same vessel. When the valves *c* and *f* are open, steam flows above the piston, and presses it downwards, when the piston reaches the bottom they are shut, and the valves *d* and *e* are opened, the piston is then pressed upwards.

The valves which appear in these figures are

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shown in the engraving marked WATT, D., fig. 2, on a larger scale: *m*, *a*, are toothed segments, fixed on spindles which are carried through the sides of the valve-boxes; *n* is a rack to which the valves *s*, *b* are fixed, and work into the toothed segments; *m*, *a*, *c* are pieces of metal against which the back of the racks slide, and serve to keep it steady, and in its place; this is also provided for by the valve-stem, *o*, (or its tail,) which moves in a ring fixed by a bracket; the seats of the upper valve are shown square, they should be champered as the lower one; the operation of the mechanism will be apparent from an inspection of the figure. Figure 3 is a section of the piston of the single impulse engine, to show the mode Watt adopted of fixing it to the stem or rod, by forming its lower end as a cone. Figure 4 is the same contrivance adapted to the piston of his double impulse engine. Figure 1 was the mode he framed his working beams; *n*, *c*, *d*, *f*, *e* are iron ties or braces, bolted to the king post *m*, and the beam *a*, or to the arched ends of the working lever; *g*, *h*, chains to which the pump-rods are fastened.

Before the arrangement of the double impulse engine could be of much use, some contrivance was necessary, by which the motion produced could be imparted upwards as well as downwards to the vibrating lever. For the chain by which the piston was attached to the working-beam, although sufficient when the steam pressed the piston downwards only, was useless when the motion was reversed. The first mechanism which Watt employed, is shewn in the engraving marked WATT, C., Fig. 1: *h*, is the vibrating lever, *x*, piston rod, and *y*, a rack fixed upon it, *o*, a toothed wheel or pinion on the axis of the fly-wheel. When the piston is in motion, the rack upon

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it moves the segment either upwards or downwards, which gives motion to the pump rod.

Watt applied the fly-wheel, *o*, in order to equalize the motion of the piston, when urged by steam acting expansively. When the piston-rod, *z*, "pulls down the end of the working-beam, the toothed sector, *x*, working the pinion *o*, thereby gives motion to the fly, and when the ascending or descending velocity of the piston becomes less than the velocity which the fly has acquired, its impulse tends to equalize the motion of the piston. The fly wheel *o* turned in contrary directions during the rise and fall of the piston. When the engine was large, this was a most inelegant and clumsy contrivance, liable to be often out of order, and produced an excessive noise at the instant when the motion was changed. This was superseded by another contrivance, which he called a PARALLEL MOTION. Engraving marked WATT, B.

"Concerning the steps by which Watt was directed to this contrivance, different representations have been given. One of these supported by the authority of Prony, is that he was led to it by the consideration of an instrument used for describing a great variety of lines on paper known, by the name of Suardi's pen.

"But this cannot be considered but as extremely unlikely. It is very true that Suardi's pen, if known to him, may have suggested the idea, that it was possible to describe, by a continued motion, certain curves, portions of which, where the curvature changes its direction, does not differ essentially from straight lines. This, however, was not a piece of information very material to be received, or such as any man accustomed to the inspection of geometrical figures could have any occasion to look for from without. But the

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information to be obtained from Suardi's pen could go no further than this, when considered relatively to the conditions under which the problem of the parallel motion was to be resolved in the steam-engine. In Suardi's instrument, the complication of wheels and pinions, and the consequent description of cycloids and epicycloids may be continued without end. When any line whatever, therefore, is described by this instrument, it is in consequence of a vast complication of motions, such as Watt, or any man working upon the scale he did, and with the means he must employ, could have no power to imitate. The complicated process of Suardi, if it could have had any effect, must have led an engineer to despair absolutely of describing similar lines by the few simple motions which he had it in his power to produce. Far from suggesting the means of overcoming the difficulties, it would have deterred him from any attempt to overcome them.

"We may conclude, therefore, with great probability, that it was not in this way the discovery was made: there is a much more natural, and more obvious view of the matter, by which we are persuaded Watt was directed, and the reasoning we suppose to have passed in his mind is the following.

"By means of the angular motion of the beam of a steam-engine, it is easy to make any point move in the circumference of a circle with a reciprocating motion. If it is the end of a beam or bar which is made to move in this manner, the other end of it may also be made to move in another circle, by fixing it with a joint to a radius, which has its other extremity fixed to a given point; we shall thus have a beam of a given length moving up and down with its extremities

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in circles which turn their convexity towards one another. Between these two extremities, therefore, it should seem, that there must be one point, that will have the convexity of its path turned neither way, if one may speak so; that is to say, will be neither concave nor convex, but straight for a certain portion of its ascent or descent. This was a simple view of the matter, such as much practice in the construction of machinery would very readily suggest to a man of ingenuity, used to reflect on the gradual transition by which all changes in the quantity or direction of motion are effected. If, after taking this general view of the matter, he should make an appeal to a geometrical construction, he would find his conjecture completely verified, and would soon perceive in what manner the data of the problem might be so varied, as to give the line described whatever position was required. It is certainly more probable, that he was guided by the simple and direct, though perhaps refined reasoning just mentioned, than by any thing so circuitous and indirect as the study of a complicated machine, with which the thing to be found out is very remotely, if at all connected."

This ingenious speculation has much to recommend it; but from Watt's habits, it is most likely that his invention was rather by a tentative process, than deduced from a chain of reasoning. There are many arrangements in the old mechanical authors, in which a thing nearly the same in appearance, and applied to a similar purpose, might from inspection have suggested a trial of something like the parallel motion: in Schottus' book there are several; but from Watt's known candour, his own account should be relied upon. When he was asked by Playfair, whether he could

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trace its invention to any previous chain of reasoning, he replied in the negative; adding, with his characteristic candour, that "he was surprised himself at the perfection of its action; and in looking at it for the first time, he had all the pleasure of novelty, which could have arisen, had he been examining it as the invention of another person."

The problem in truth, is, however, a very easy one, and after this solution of it, other combinations were produced which have in many instances superseded his, or rather some ancient schemes were revived whose application had now become apparent.

Figure 1 is a side view, and figure 2 an end view of the *parallel motion*, as it was applied in the first engines which acted with a double impulse. The main links, *e*, *e*, are connected to the working beam and to each other by the cross-pin *i*, and to the piston-rod by a similar cross-pin, the ends of which are shown at *b*, in figure 2. The back links, *d*, are also attached to the working-beam by a cross-pin, and the parallel rod *b*, is fixed to the lower end of the back and main links, *d*, *e*, in the same manner. One end of the radius, or bridle rod, *c*, is attached to the back links by the pin which attaches them to the parallel rods, and the other end *h*, is fixed by another cross-pin to the spring-beam *m*. These cross-pins are the axes on which the links and rods move in certain directions: as the beam descends, the pin connecting the bridle and parallel rods describes an arc of a circle, which is turned in an opposite direction to the arc of a circle that is described by the pin *i*, fixed on the lever-beam, but having about half of the deviation; this being transmitted by the parallel rod *b*, to the cross-pin at the lower extremity of the main link,

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e, the compensation causes the end of the piston-rod to descend or ascend in a curve, which in practice approaches so nearly to a right line as to answer all the purposes of a perfectly true rectilineal motion. In the figures the same letters refer to the same parts: *f* is the supply pump-rod; *k*, the axis of working-beam. Watt gave some other varieties of combinations of levers, but not differing in principle from the one described, which is now known among mechanics as THE PARALLEL MOTION.

The contrivance prodigiously increased what were called the capabilities of the engine, and little more was now wanting to its most perfect form, than some scheme by which the alternate motion given to the great lever could be converted into a rotary one.

The crank, as we have already seen, was appropriated to this purpose by Pickard, who could prevent its use by another. Watt, who to use his own expression, "did not choose to demolish the patent, and thus lay the invention open to every body," sought to accomplish the same purpose by other means; and the *sun and planet-wheels* motion,—a perfectly novel combination in mechanics,—by which he accomplished his purpose, was in some cases preferable to the rival method. It has not been stated whether Watt employed it before he erected the celebrated engines at the Albion Mills. As it appeared there applied on a great scale, it is shown in figure 2, in the engraving marked WATT, C: the reciprocating motion produced by the rise and fall of the lever *h*, is converted into a continuous rotary motion, by connecting a toothed wheel *b*, to the inflexible rod *c*, *d*, *f*, which is attached to the curved end *g*, of the lever *h*, by a pin *f*, which serves also as its axis.

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A toothed wheel *a*, is fixed on the axis of the fly-wheel *i*: the *planet*-wheel *b*, being fastened to the connecting rod so as not to turn on its own centre, as the beam rises it is drawn up on the circumference of the *sun*-wheel, and turns it round, causing the sun-wheel to make two revolutions while the planet-wheel travels once over its circumference; the momentum of the fly-wheel being sufficiently powerful to preserve the tendency of the machinery to revolve in the same direction during the change of the motion in the piston, and to urge the planet-wheel over the inactive points in its circuit.

About the time when Watt erected these engines, the attention of the court of Spain had been drawn to the state of its American mines, from some of the richest veins becoming nearly unproductive, in consequence of the enormous expense, and difficulty of keeping them clear of water. Several of them required an outlay of ninety thousand pounds a year for the expense of drainage, and required the labour of from twelve to fifteen hundred horses to get the water alone to the surface. The power of steam-engines had been suggested to supersede that of animals. A Frenchman, Bettancourt, who had distinguished himself as an engineer, was authorized by the Spanish government to proceed to England, for the purpose of collecting information regarding steam-engines, with reference to their introduction into South America. Bettancourt visited Birmingham, and received from Bolton and Watt the most ample and unreserved explanation of their wonderful machines. During his residence in London, he had an opportunity of inspecting the far-famed machinery of

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the Albion Mills, and the principle of the apparatus which actuated the whole: the double impulse engine was explained to him on the spot, either by Watt or Bolton. Considering how many men were employed in the mill, and dependent upon it, it was not to be expected that either of these gentlemen should request the proprietors to stop the machine, merely that a stranger might gratify his curiosity by a minute inspection of the parts. Bettancourt, therefore, saw this machine at work only, but the concealment of any part of the mechanism was not intended. In fact, there was nothing in the construction of the double impulse, which should not have been evident upon a mere inspection of its external parts, to any one who understood Watt's single engines, which Bettancourt had a full opportunity of doing, even before he came to England, by examining that made by Bolton and Watt for the Periers, and erected at Chaillot in the year 1779, to supply the city of Paris with water. On his return, Bettancourt, during his residence at Paris, gave instructions to the Periers for a machine having a double impulse: the form of valves, and one or two minor details, were however his own design, and these are the most imperfect parts of the engine. Prony describes this engine, and almost insinuates that Watt and Bolton in shewing Bettancourt the engine at the Albion Mills, had concealed the mechanism of thy valves: and on account of the defective additions by Bettancourt, and their construction be the Periers, he founded for them a secondary claim to the invention of the engine, and for a long time succeeded in transferring to them, in the

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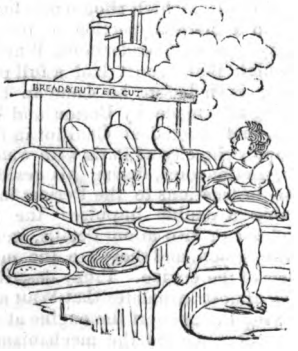
eyes of the greatest part of the continent, the merit of inventions which belong exclusively to Watt.

At a latter period, when this was mentioned to Watt, by Playfair, as requiring to be contradicted for the sake of his own reputation, Watt, who was indeed indifferent to it, replied, that he believed the mis-statement had been pointed out to Prony, who had also promised to apologize for the error and to correct it. But the philosopher lived thirty years afterwards without finding an opportunity to perform this act of justice.



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CHAPTER EIGHTEENTH.

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"THE WISHED-FOR IMPROVEMENT IS UNMADE, OFTENER BECAUSE THE MEANS ARE OVERLOOKED, THAN BECAUSE THEY ARE HIDDEN FROM US."—*Warburton.*

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THE ingenuity which had been exerted in overcoming the greater difficulties, had yet an ample field left for its exercise, in regulating and transmitting the power after it had been produced. One of the defects of the apparatus, which was most insisted on, was the irregular production of the steam, from the varying heat of the fire under the boiler giving an unequal pressure to the piston.

A similar irregularity in the motion of corn-mills, from the varying force of the impelling or resisting forces, had early exercised the ingenuity of millers. For as the stones moved faster or slower, the meal which was produced was small in quantity, and too fine, or it escaped in a state not fine enough. One of the modes by which this defect was remedied, was by making the stage on which the spindle of the mill-stone rested, so as to be raised or lowered, to preserve a uniformity in the pressure of the stones upon the grain. This was in many cases done by hand; but it was in

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others done by what was called a *lift-tenter*, which operated as a self-acting regulator. This was a ball, fixed to a jointed rod, which was made to revolve by a cord proceeding from a pulley fixed on it, and which received its motion from the mill-stones; this ball was attached to the stage, or "bridle." As the mill-stones revolved, faster or slower, the ball at the end of the jointed rod rose or fell by its centrifugal motion, from the perpendicular to the horizontal direction; and this, as it might be adjusted, raised or lowered the stage on which the mill-stone spindle revolved. Mr. James Mead, an ingenious mechanic at Hull, had also applied this elegant contrivance to regulate another part of wind-mill machinery. He attached a lift-tenter so as to receive its motion from the axis on which the sails were placed, and by means of cords and pulleys he made it an excellent regulator of the varying velocity. When the wind was impelling the sails with too much rapidity, the balls of the lift-tenter gave motion to a mechanism by which a part of the canvass was furled; and as the speed of the air diminished, the fall of the revolving balls acted to unfurl the sails, and spread a greater surface to the aërial current, by which means the motion was equalized.

A Mr. Clarke, of Manchester, suggested the application of this fine mechanism to the regulation of the flow of steam from the boiler into the cylinder. The two balls, *a*, *b*, fixed to the levers *c*, *d*, have their common fulcrum at *e*, and are attached to other levers, *m*, *n*, fixed by a moveable joint to a slider, *o*, moving freely up and down on the vertical rod, *x*. The horizontal lever, *i*, has its fulcrum at *i*, and raises or lowers another lever at *r*, which is attached to a valve *z*, in the inside

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of the pipe. On the pulley is a cord *g*, proceeding from the *fly-wheel;* by this means a rotary motion is given to the vertical rod, and the balls, by their centrifugal force, rising outwards, draw downward the slider; this last movement raises the opposite end of the horizontal lever *i*, which, acting on the lever, *r*, opens or shuts (as it may be adjusted) the valve *x*, in the inside of the pipe *f*, and diminishes or enlarges the area by which the steam flows into the cylinder. The fall of the balls, when the motion decreases, reverses all these movements; and by thus enlarging or contracting the steam-way, and admitting more or less steam into the cylinder, the impulse of the piston is rendered much more uniform. The valve has since received the name of the *throttle-valve*, the conical pendulum that of the *governor*. We know not if Clarke ever carried his invention into practice; but if he did not, his suggestion fell on a genial soil, and Watt's introduction of it as a governor, or regulator of motion, was the last great improvement his engine was to receive from his hand. It has sometimes been described as having been invented by Watt; but that great mechanic was incapable of appropriating to himself an idea which belonged to another.

In the same document, in which Watt described what is now called the parallel motion, he gave an account of an adaptation of his mechanism to the propulsion of land carriages. The boiler of this apparatus, he proposed, should be made of wooden staves, joined together, and fastened with iron hoops, like a cask. The furnace to be of iron, and placed in the inside of the boiler, so as to be surrounded on every side with water. The boiler was to be placed on a carriage, the wheels

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of which were to receive their motion from a piston working in a cylinder, the reciprocating motion being converted into a rotary one, by toothed wheels, revolving with a sun and planet-wheel motion, and producing the required velocity by a common series of wheels and pinions. By means of two systems of wheel work, differing in their proportion, he proposed to adapt the power of the machine to the varied resistance it might have to overcome from the state of the road. A carriage for two persons might, he thought, be moved with a cylinder of seven inches in diameter, when the piston had a stroke of one foot, and made sixty strokes a minute. Two cylinders might also be employed to act on the wheels, and the steam, after it had raised the piston, might be allowed to escape into the atmosphere.

About this period, another attempt to extend the use of steam power to navigation was made by the Marquis de Jouffroy, in 1782, on the Saone, at Lyons. In his experiment a single condensing engine turned two wheels, one placed at each side of a boat 140 feet long. But, although his model was constructed with some skill, and with all the experience arising from a knowledge of d'Auxiron, and Perier's trials, Jouffroy's experiments did not inspire very sanguine hopes of his being able to make the vessel move briskly against the current of the river. The framing of the parts of the propelling machinery having been but slight, the apparatus was so much deranged in the trials, that from the expenses of repairing it, the Marquis postponed his further operations from time to time, until, by the political troubles of his country, he was not only obliged to give up his scheme, but to leave France; and his pe-

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cuniary means were not, for thirty years afterwards, so flourishing as to enable him to renew them.

The great practice of the Messrs. Hornblowers in the erection of steam machinery, in its application to mining, gave a weight to their opinion to which it had been more entitled had it been less interested. Watt, it has already been stated, employed the expansion of steam; and Falck, evidently, without suspecting the contrivance, recommended the two cylinders; but in giving a new form to both ideas, the mechanical means employed by the Hornblowers, were well understood and ingenious; they connected the two cylinders *c*, *d*, by a pipe *a*, and one was joined to the boiler by the pipe *e*; *f*, opened or shut a communication with a condenser and the cylinder, *d*. These vessels being first filled with steam, the cocks *o*, *o*, shut, and the communications between the top and bottoms of the cylinders also interrupted, the injection-cock *f*, being opened, a vacuum was made under the piston *d*, and steam flowing from the under side of the cylinder *c*, into the upper part of the cylinder *d*, depresses the piston *d*, into the vacuum beneath it. But, during this operation, the steam issuing from the boiler through the pipe *e*, presses down the piston *c*, which arrives at the bottom of the cylinder at the same moment with that in the other cylinder. The further flow of steam through *e*, being stopt, by shutting the cock *w*, and the communication by the pipe, *a*, between the cylinders being also interrupted by the cock, *a*, the valves, *o*, *o*, being opened, and the condenser-cock, *f*, shut, the pistons *c*, *d*, may be drawn up to the top of their cylinders by means of a counterpoise fixed at the end of a balanced lever, and the vapour which is displaced by their ascent flows through

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o, and *v*, into the space under each piston. The apparatus is now ready to make another stroke.

The cocks or valves, *e*, *a*, *f*, are opened at nearly the same moment, and *o*, *o*, shut. The steam under *d*, rushes through *f*, into the condenser, *x*, placed in a cistern of cold water, and is instantaneously condensed, and the steam from the under side of *c*, expanding through *a*, again presses *d*, downwards into the vacuum, at the same moment while the vapour from the boiler of double the density of that in *c*, presses the piston, *e*, also into its cylinder. And when they have reached the limit of their stroke, the cocks, *e*, *a*, *f*, are shut, and *o*, *o*, opened, and the pistons are again raised to the top of their cylinders as before. The air and water accumulated in the condenser is drawn out by a pump, *r*, as has been described in Watt's engine. The mechanism by which the cocks were opened and shut, made the apparatus a self-acting one, but they are omitted in the figure, not to confuse it. Some of the minutiæ were, however, novel and ingenious, especially the arrangement and form of the cocks.

It will have been observed, that this mechanism, as it has been described, combines all Watt's inventions with that which Hornblower thought was an idea of his own,—the use of a second cylinder. But Watt was in possession of the sole right to use a separate condenser; and Hornblower's attempt, by varying the construction to make use of the same principle, was an infringement on the legal right of Watt; and which, many years after this period, became the ground of an action, brought by Bolton, against some parties who had used Hornblower's machine; and although Hornblower stated his engine to have a power equal to sixteen, while Watt's, with the same quantity of coal,

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could not be rated higher than ten; his theoretical deduction was not borne out by practical observation, and it was affirmed by his rivals that it even fell far short of their common engines; a Mr. Wilson, who was an agent for the introduction of Watt's engines in Cornwall, resorted to a well known English mode of deciding a knotty or doubtful matter. He offered to bet a large sum of money, that he would erect an engine, on the same mine, using the same quantity of steam, produced from the same quantity of coals, that should do more work than that which he challenged Hornblower to erect on his own plan on this occasion. But the bet was prudently declined. In fact, there could not be a doubt that Hornblower's mechanism, although ingenious and skilfully combined, was deficient in principle, even in the part in which he considered the improvement to rest—the introduction of a second cylinder—and there could be still less doubt, that, but for his making use of Watt's condenser, it would have remained at an infinite distance from the Soho engine in every thing *.

Viewing this matter, however, in its true light, and considering Hornblower—the first who openly entered the field of competition with Watt—as excited by the feelings which mercantile rivalry often creates, his ingenuity merits our approbation, and its failure is entitled to our sympathy; for it were, indeed, ungenerous, as well as unjust, to consider his hostile opposition to Bolton and Watt as emanating solely from himself, when, in fact, he was only thrust in front of the battle by a part of the Cornwall mine-proprietors,

* At the expiration of Hornblower's patent, he petitioned Parliament for an extension of the usual term of fourteen years, but the application was not attended to.

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whose cupidity was excited by the great gains Bolton and Watt drew from their monopoly These ungrateful mine owners, looking only to the "third part" of the saving reserved by the patentees, forgot the other *two-thirds* which rested in their own pockets. The Hornblowers, however, were eventually obliged to abandon their pretensions; but not before they had nearly ruined themselves. One of the brothers emigrated to Sweden, where he was employed by a native of that country from a respect for his talents, which were considerable, and who valued him for his integrity, which had never been impeached.

The different construction of Watt's valves required a new arrangement of the hand-gear to move them. In the atmospheric engines, the weight or tumbling-bob at the end of the levers, called the Y piece, was placed there, so that its fall should open the sliding valve, or the injection-cock, with a jerk; it exerted no influence whatever, in keeping the valves in their places, at least it was not introduced for that purpose. Watt also sometimes attached a weight to the spanners, which opened or shut his valves. But it was necessary in some arrangements of these parts, that they should be gradually shut, to prevent the injury that would be occasioned by a sudden jerking of the valves into their seats. This weight was, therefore, sometimes formed like a piston, which rose and fell in a cylinder filled with water. The weights, or plungers, were made of cast-iron, and cylindrical, each fitted into a hollow cylinder, placed in the condensing cistern, and covered with water; the plunger is made somewhat less than the barrel, to allow a small space, by which, when it descends, the water may rise between it and the barrel; the lower end of each barrel is

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closed, except a small hole, which is covered by a leather valve opening inwards. When the plunger is drawn up, the water from the cistern flows through this valve into the barrel, but when the plunger descends, the valve closes, and the water which is displaced rises between the plunger and barrel, and the resistance which is thus occasioned to the descent of the weight prevents the concussion which would be produced by its uninterrupted fall, and at the same time affording a means of making the weight sufficiently heavy to open the valve. *a* is the plunger, *b* the barrel, *c* the barrel valve, *d* the rod from the steam valve.

These weights, instead of falling into the water, sometimes were hung on horizontal levers, which moved on a joint; the weights were moved backwards and forwards upon the levers or treddles, so as to act with a greater or less force in opening the valves as they might be adjusted. In the figure 2, *a b*, are the treddles, and *c d*, the weights hung upon them, *e f*, are the rods attached to the spanners or valve levers.

The single-impulse machine of Watt for pumping water, may now be shortly described; *a*, the working cylinder; *b*, the piston; *c*, the steam valve; *d*, the equilibrium valve; *e*, eduction valve; *f*, condenser; *g*, jet pipe; *h*, condenser or air-pump; *i*, cistern into which the hot-water is pumped from the condenser, and from which the boiler is supplied; *k*, the cold water cistern in which the condenser is placed by the pump *o*; *l*, is the plug-frame; 1, 2, 3, spanners or levers attached to the valves *c d e*; *m*, equilibrium pipe; *n*, great lever; *o*, cold water pump; *p*, mine pump; *q*, tumbling-bob; *r*, pipe from boiler; *s*,

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regulating valve, or throttle valve, which is shown as moved by hand in the engraving.

The pipe *t* connects the condenser with its pump barrel, and has a valve at *u* opening inwards. The pipe *w* conveys the air and water which is drawn from the condenser through the valve *w* into the hot water cistern. The pump *y* raises the hot water from the cistern *i*, to supply the boiler. The cistern *k*, is constantly replenished by the pump *o*, with cold water, drawn from the mine, so as to keep the temperature of the fluid, in which the condenser is immersed, as low as possible; the water which has become heated is allowed to escape by a pipe, which is not shown in the figure; its position is immaterial. The steam-cylinder is fixed on a foundation of solid masonry, and the other parts of the apparatus are firmly united to each other, so as to ensure the greatest possible truth in the various working bearings of the mechanism.

In the figure, the parts of the engine are shown as if the operation of expelling the air from the interior of the cylinder and condenser has been completed, and the machine in a position to begin its first working stroke.

The steam valve *c*, and the eduction valve *e*, are open, as also the injection cock; that part of the cylinder, therefore, beneath the piston, communicates with the condenser, and the upper side of the piston is open to the action of the steam from the boiler. When the piston is forced by the steam downwards, nearly to the bottom of the cylinder, the plug-frame *l*, which is attached to the great lever *n*, also descends, and the tappets, 7, 8, fixed upon it, strike the spanners or valve levers 1, 2, 3. This action shuts the steam valve *c*, and the educ-

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tion valve *e*, and opens the equilibrium valve *d*; the motion of the piston is thus instantaneously destroyed; for the steam which lies above the piston being admitted through *d* beneath it, it is placed in equilibrium, and at this instant the counterpoise on the opposite end of the great lever begins to weigh it upwards.

During the descent of the steam piston, the piston of the air-pump also moved from the top to the bottom of its cylinder, and as its descent compressed the air beneath its valves, these opening only in the upward direction, are lifted up, and when the piston has reached the bottom of the cylinder, all the water also which had accumulated from the injection, and had flowed through the pipe A, will lie on the top of the piston; the rise of the lever beam, by the counterpoise, also elevates this air and injection water, and it is expelled through the pipe and valve *w* into the cistern *i*.

At the moment when the counterpoise has raised the steam-piston a second time into the position shown in the figure, the tappets on the plug-frame strike the valve levers, and the entire action of the machine is reversed; *c* and *e* are here opened, and *d* is shut; and by this means a vacuum being produced below the piston, the pressure of the steam above it forces it downwards as before.

The rods attached to the pumps for raising water from the mine, and for supplying the cold water cistern, and replenishing the boiler from the hot water cistern, being fixed on the opposite end of the great lever, are raised and depressed in the same manner, as has been noticed in the description of former engines.

The steam has been described as operating with

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its unimpaired energy during the entire stroke, but adjusting the tappets, so that they may strike on the steam-valve lever, and shut it, when the piston had reached a certain point in its course; the steam would then be said to act expansively.—The small size of the figure precludes an exhibition of some of the minor details. Among those omitted, which are usually placed on all engines, is a rod which is attached to one end of the valve-levers, having the plunger, or a weight, suspended at its extremity; the tendency of which weight is to open the valve, as has been described. Each lever is further provided with a catch, which acts to keep the valve shut, when the weight has been raised by the plug-frame. When this detent is unlocked, the valve opens, and one catch is connected with the other in such a way, that when the spanners of the steam and exhausting valves are released, that of the equilibrium valve is locked. The injection valve is also attached to the eduction valve, so that when the latter is opened, the strap, or chain, which connects them, opens the injection valve also.

The ends of two iron pins project outwards from the arch-head of the great lever, in order that they may strike on the upper springs of the spring beam B, and thus limit the length of the stroke of the piston, should it at any time, through accident, have a tendency to exceed its regulated limits. "It once happened that the valve of the pump-bucket breaking, the engine suddenly lost its load or resistance, which occasioned the piston to descend, and strike on the spring beams for two or three successive strokes, with such violence as to make the great piston rod quite crooked. To prevent similar accidents, a smaller steam pipe was added at the side of the vertical

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steam pipe, communicating with the passage into the bottom of the cylinder. This pipe is kept closed by a valve, but if the engine descends so low as to strike on the spring beam, a catch pin on the beam strikes a small lever, and by a wire of communication opens the valve, and lets the steam into the lower part of the cylinder beneath the piston, and this destroys the vacuum so as to prevent the further descent of the piston."

The usual way of making the joints in the atmospheric engines, and which was also practised by Smeaton, was to interpose a thin ring of lead, covered with glazier's putty, and to compress it very firmly between the flanges by means of screws. This was found to be sufficient for the joints of the atmospheric engine, but Watt's engine required joinings made with much greater delicacy, as the air had to be excluded from every part of the apparatus with the nicest care, since its presence, even a small quantity, greatly impaired the energy of the mechanism, while, in the atmospheric engine, this was not so sensible. Instead of lead for the rings, Watt employed pasteboard; cut to fit the flanges, and then soaked in warm water until it had become quite soft; each piece was, in this state, laid upon one of the flanges it was finally to be placed between, and small weights being laid upon it, it was left in that position until it was quite dry. After being thus moulded and adapted to their places, the pasteboards were laid in a flat vessel, and covered with drying linseed oil, (heated to 212° by a water bath,) and were allowed to soak in it until they emitted no air bubbles; they were then taken out to be used, and being anointed on both sides with thin putty, made with very fine dry whiting, incorporated with the same drying oil,

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and being interposed between the flanges, which were previously made as smooth and true to each other as possible, they were firmly compressed by screw bolts. White lead was tried as a substitute for the whiting, without being an improvement; the joints were good at first, but required to be often renewed: the method was subsequently changed for one more perfect; for this also we are indebted to Watt: and, like every thing he produced, it is still the best of any in use; and so perfect, as to leave little to be wished for; different artists may deviate a little in the proportion of the ingredients, Watt's is, however, entitled to the preference. He took sixteen parts of clean cast-iron filings, or borings, two parts of muriate of ammonia, and one part of flowers of sulphur, and mixed them well together in a mortar. This powder he kept dry until it was wanted for use; when to one part of it he added twenty parts of iron borings, and mixed them well by trituration in a mortar. He then added as much water as made the compound into a paste, and introduced it into the joint, which was then firmly united by screws. A chemical action was found to take place between the cement and the faces of the iron, which formed the joint, which scarcely left any thing to be wished for on the score of the most perfect impermeability to steam or air, or to the durability of the joining *.

* Powdered quicklime, mixed with bullock's blood, is often used by coppersmiths to lay over the rivets and edges of sheets of copper in large boilers, as a security to the junctures, and also to prevent cocks from leaking.

Six parts of clay, one of iron filings and linseed oil, sufficient to make a thick paste, make a good cement for stopping cracks in iron boilers.

Boiled linseed oil, litharge, red lead, and white lead, mixed together to a proper consistence, and applied on each

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The barometer gauge, which has been described as placed on the cylinder to indicate the degree of force of the vapour within, was found by Watt to be an inconvenient instrument, and objectionable on account of the great vibration of the mercurial column, during the exhaustion of the cylinder, preventing the possibility of making any correct observation. He employed another device, which he called an indicator; this was a small truly bored cylinder, *a*, from 1½ to 2 inches in diameter, and from 7 to 9 inches in length, fitted with a small piston *b*, having a stem projecting upwards above the cylinder; round the lower part of this stem a spiral spring, *c*, was coiled, one end of which he fixed to the small piston, and the other end he fixed to a frame or bracket; above this bracket he placed a scale, and the upper part of the piston-stem acted as an index, to point out, in degrees of this scale, the rise or fall of the small piston.

The indicator being fixed to the cylinder, one end is open to the air, and the other to the inside of the cylinder; when the cylinder is filled with air, the pressure is equal on both sides of the indicator-piston, and the worm-spring is adjusted then not to exert any of its elasticity; this is the point of the scale equal to O. When, however, a vacuum is made in the cylinder, the pressure of the atmosphere on the upper side of the indicator-piston will extend the spring by pressing the small piston downwards; and the fall of the index

side of a piece of flannel, or even linen or paper, and put between two pieces of metal, before they are brought close together, will make a close and durable joint, that will resist boiling water, or even a considerable pressure of steam. The proportion of the ingredients are not material, but the more the red lead predominates, the sooner the cement will dry: and on the contrary.—URE's *Chem. Dict.*, p. 306.

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to different points, as the vacuum is made more and more perfect, will give points on the scale, indicating, with great precision, the degrees of exhaustion in the steam cylinder; therefore, when the working cylinder is filled with steam, the indicator-piston will rise, being drawn up by the contraction of the worm-spring; and when the steam flows into the condenser, it will fall to that point corresponding to the degree of vacuum in the condenser and cylinder, the worm-spring being pressed by the weight of the atmosphere. In fact, the indicator-piston is a correct, though miniature exhibition of the various degrees of force exerted by the steam on the large piston of the engine. A card is sometimes substituted in the place of the scale, and a pencil is fixed in the end of the stem, or index—so as to trace upon the paper the rise and fall of the indicator-piston, and thus preserve a record at any particular time of the operation of the machine. This elegant addition is mentioned here, although out of its place (by a few years in the order of time), to give a more concise idea of the mechanism of which it forms a part. It is stated to have been made by a Mr. Douglass, a person in the employ of Watt and Bolton, in 1789.

The engraving marked WATT, represents a section of his double impulse, or rotative engine, and the engine is that which he erected to move the machinery at the Albion Mills. *a*, the steam cylinder; *b*, the piston; *c*, the parallel motion; *d*, the plug frame; *e e*, steam valves; *f*, *f*, their levers; *g g*, exhausting or eduction valves; *h*, *h*, their levers or spanners; *i*, pipe to condenser; *k*, condenser pump; *l*, its piston; *m*, injection valve; *n*, second condenser and air pump; *o*, hot-water cistern; *o*, governor, or conical pendulum; *p*, lever

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connecting it with the throttle-valve *g*; *r*, hot-water pump for supplying boiler with the water heated by the injection; *s*, cold water pump for supplying condenser cistern; *t*, planet wheel; *u*, sun wheel; *w*, rod connecting the planet wheel with the great lever *w*.

From the ample description that has been given of the details of all the parts as they were invented, a brief account of the action of this exquisite machine will suffice, to make it clearly understood. In the figure, a communication is open between the under side of the piston and condenser, and between the upper portion of the cylinder and the boiler, and the piston is at the instant of beginning its downward stroke. When it has moved through nearly three-fourths of its whole course, the fall of the plug frame makes the tappet 1, strike on the spanner 2, and this shuts off the further supply of steam from the boiler, and the piston is carried downwards by the expansive property of the vapour within the cylinder; as the piston reaches to nearly the limit of its stroke, the plug frame disengages the catch (not shown) which retained the shut exhaustion valve in its position, and allows the fall of the plunger weights to open it; a communication is thus formed between the upper side of the piston and the condenser. At the same moment that the catch was unlocked from one valve, the other exhausting valve was shut and retained in this position by the other end of the catch, while the steam valve connected with it opens at the same moment. The pressure of the vapour is now under the piston, and the vacuum above it, the motion is thus reversed, and the piston is pressed upward, and so on alternately. The action of the air-pumps is the same as that in the single engine;

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and the impulse, both upwards and downwards, is transmitted to the balanced lever by the parallel motion. The alternate action of the lever would also produce a reciprocating action at the end of the planet wheel rod; but this wheel is prevented from moving in any part but in the orbit of the sun wheel, and the impulse which the fly wheel has received during the movement of the working beam in either direction, carries the planet wheel beyond its inactive or neutral points, and thus not only equalizes the motion, but makes it a continuous rotary one. A cord or strap, *z*, proceeds from a pulley on the axis of the fly-wheel, and goes round another pulley on the spindle of the governor; as the motion of the fly wheel is fast or slow, so is also that of the governor, the balls fly outwards as the speed increases, the lever *b*, is depressed, and this being connected with the lever that moves the throttle-valve, which is adjusted to diminish the area for the steam, when the balls fly outwards, and it is opened or enlarged when, in their revolution, they fall nearer to their spindle.

The mechanism of the vessel which generates the vapour, that actuates this powerful machine, also received some ingenious additions from the hand of Watt; and the boiler of the engine he constructed for the engine which has just been described, was the first that had any pretensions to be considered as a self-acting, as well as a self-regulating apparatus.

The upright pipe *a*, by which water was introduced to supply the place of that which had been converted into steam, descended through the roof of the boiler, and its lower end was inserted into the water; the other rose on the outside, so high as to allow an elevation of about 34 or 36 inches for each pound weight, that the vapour in the boiler

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could support, above the pressure of the atmosphere; as Watt seldom used vapour of a greater temperature, than to balance about 3 pounds weight above the atmospheric pressure, the feed pipe seldom rose higher than 9 or 10 feet above the medium level of the water in the boiler. The top of this pipe was formed into a small cistern *c*, having a valve *d*, opening upwards; the stem *e* of the valve was fixed to a horizontal lever *f*, poised on a bracket *g*; a thick wire *h* was suspended from one end of this lever, and worked in an air-tight manner through a box *i*, having a flat stone suspended at its lower end, so as to float, as it were, on the surface of the water; and to compensate for the greater specific gravity of the stone, a weight *k*, was hung at the opposite end of the lever, and the stone-float, thus made buoyant on the surface of the water, rose and fell with every change in its level.

When, therefore, by the generation of steam, the level of the water fell, the stone-float fell likewise, and drew up the valve *d*, and allowed the water which lay above it in the cistern, to descend through the pipe into the boiler; as the water rose in the boiler, the float rose also, and this shut the valve. By this contrivance, it will be apparent, that no water could flow into the boiler beyond the limit which was set by the adjustment of the valve, as this shut when the water raised the float to a certain height, and by this means the necessary quantity of steam was always preserved for the supply of the cylinder.

By the valve *x*, Watt also provided for another contingency in the use of this engine. When the space in the boiler above the water was filled with steam above 212 degrees, the weight of the atmosphere had no tendency to crush the boiler; but

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when, by any casualty, the vapour was condensed, some contrivance was necessary to prevent the sides of the boiler being pressed inwards by the weight of the air. The valve x opens downwards, and is kept closed by a lever z, having its opposite end loaded with a weight. When the dome of the boiler is filled with vapour of the ordinary elasticity, this weight keeps it closed, but as soon as the condensation of the steam forms a vacuum within the boiler, the pressure of the atmosphere preponderates and thrusts the valve z downwards, and the air then fills the space which had been occupied by the vapour.

The mode by which Watt allowed the steam to escape when its elasticity had a tendency to burst the boiler, differed from Smeaton's * and Sa-

* JOHN SMEATON, F.R.S., was born at Austhorpe, near Leeds, in 1724. At the age of fifteen years, he had made all his own tools for working in wood and metal; and among other things a lathe, by which he cut a perpetual screw in brass, a contrivance at that time little known, and of which the invention is ascribed to a Mr. Henry Hindley, of York, an inventive mechanic of the first order, with whom the young artist afterwards formed a lasting friendship. Smeaton, having given up the study of the law, practised in London as a watchmaker, and became well known among scientific men for his great skill. In 1763, he was admitted into the Royal Society: in the succeeding year he visited Holland, travelling mostly on foot and in passage-boats, to make himself master with greater ease of the mechanical contrivances of these countries. The Earl of Macclesfield, at that time President of the Royal Society, being applied to by some Members of the Trinity House, to recommend a person who could be entrusted with the erection of a new lighthouse on the Eddystone rock, although his Lordship knew Smeaton had no practice in such works, yet his character for caution and skill stood so high, that he was pointed out by the Noble President as the only person who posssessed the qualfications both of mind and habit, which were required to carry so arduous a design into execution. Smeaton's success more than justified the expectations that were formed of him; the Eddystone Lighthouse ranks as one of the grand productions of

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very's only in the valve being inclosed in a steam-tight box, the spindle of which moved through a stuffing box, and was attached to a short lever; by this means, the vapour, instead of escaping into the atmosphere at once, was conveyed through a

the age, and the account he gave of his operations is a model for that kind of writing.

The erection of this Pharos established his reputation; and his after labours are connected with almost every great public work of his time; ample details of which will be found in his "Reports," published after his death in 1797. He had an appointment on the Derwentwater estates—directed the improvements on the River Calder—on Ramsgate Harbour—on London Bridge—and on the Forth and Clyde Canal, &c.

"The rule of his practice," says one of his biographers, "and one which he adhered to with the most undeviating firmness, was never to trust to deductions drawn from a theory, in any case where he could have an opportunity of trial. As he got older, he used to say, 'Care not about any theory at all. A man of experience does not require it. In my intercourse with mankind I have always found those who would *thrust theory into practical matters, at bottom, to be men of no judgment, and pure quacks.* In my own practice, almost every successive case would have required an independent theory of its own; theory and quackery go hand in hand.'"

He spent much of his leisure in the cultivation of practical astronomy, and had a small observatory at Austhorpe, which was furnished with some excellent instruments. His manners were simple, his mode of life strictly abstemious; and, above all, he was moderate in his pecuniary ambition.

Smeaton appeared to Playfair "as a man of excellent understanding, improved more by very extensive experience and observation, than by learning or education. He had much the appearance of an honest and worthy man; his manners not much polished; his conversation most instructive in every thing that related to mechanics, or the business of an engineer;" but in conversation the embarrassment of his language was very great.

"Smeaton," says another of his biographers, "had a warmth of expression, that might appear, to those who did not know him, to border upon harshness. But if he was sometimes hasty and impetuous in his disposition, he would always listen to reason."

About 1786 his health began to decline, after which he gradually relinquished professional employment. He died in 1792.

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pipe into the chimney. The gauge cocks, *n n*, have been already described; *r* is a pipe by which the boiler can be emptied at pleasure; *s*, an opening called the man-hole, to allow a person ingress into the interior of the boiler, is covered with a plate fastened by screws; *t*, is the grate on which the coals are laid; 1, 2, 3, flues; 4, the door of the furnace; 5, ash-pit; 6, pipe conveying steam from the boiler into the cylinder; 7, damper, which is the same as that used by Smeaton; 8, the pipe for showing the height of the water by inspection*; O, a barometer for exhibiting the elasticity of the vapour in inches of mercury.

The fire place under the boiler also attracted Watt's attention; and reviving the furnace which had been occasionally used by the alchemists, and which they called the *athanor*, he made the air which was to promote the combustion, mix with the smoke by traversing the surface of the ignited fuel; instead of rising through the grate bars, as in the ordinary method, the fuel he made to fall into the furnace from a hopper. He also proposed using *two fires*, one placed beyond the other; on the outer grate he laid crude fuel, and on the inner grate the fire was made with charcoal only. The smoke which escaped from the fuel burning on the outer grate, passed over the ignited charcoal placed on the second grate, and inflamed the combustible matters before they could pass into the chimney. The first scheme Watt successfully reduced to practice; but whether he could have done much with the second is very doubtful.

Such is a general outline of the parts and action of Watt's celebrated mechanism. In a technical description, for the purpose of practical or theo-

* See page 302.

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retical illustration or reference, it might be necessary to enter more at large into the minutiæ, and adjustment of the parts of which it is composed. But in our little book, addressed, as it is, to general readers, these would be altogether out of place. Here a popular notice (in its chronological position) of the *action* of a machine, supposing it to be constructed, is all that can be attempted. And in enumerating various subsequent inventions, even still greater brevity than that which has been used, will distinguish these descriptive sketches; for probably it would be considered a very idle labour to describe, at length, many projects which have been produced; some of them are first thoughts, and as such, worthy of preservation for their ingenuity, but yet requiring no minuteness of detail, to make the thought or experiment of use to others. To dwell on the mode of joining the parts, and of adjusting the secondary mechanism, would, in these cases, be absurd.

The steam machine that was invented by Mr. Robert Cameron of London, in 1784, and which he called a heliacal rotary engine, was, after Watt's, the first of a long series of attempts to obtain a rotary, instead of an alternating movement from the action of the steam; it was formed by a piston, which moved in a path made in the cylinder; the axis on which the piston was fixed, acted like a screw moving forwards, at the same time that it revolved about its centre of motion. Another of his schemes was to move a piston in a circular channel; but his third contrivance, which is a variation of the atmospheric engine, had more pretension to practical merit, than his rotary projects, and was applied to draw coals out of a pit at Mountnoor, and to turn a mill at Battersea, near London. The cylinder had a partition in

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the middle of its length, the piston rod passed through it, and had two pistons, one working in the upper division, and the second in the lower. The upper compartment above its piston, was open to the air, the lower to the steam, and the injection was introduced into the cylinder, under the piston, while the other piston served the purpose of an air-pump.

This was a clever arrangement of Newcomen's engine, but yet it could only be introduced where it was decided to use an atmospheric apparatus, even although consuming three times the fuel than was sufficient to work Watt's condensing engine. But it is true that this and similar schemes found patrons; for from prejudice, or some less worthy motive, there were individuals, who would not accept the boon of Watt's improvement, although, by doing so, they would save a great sum annually, because the inventor insisted on having a part of this saving, as a reward for his ingenuity.

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CHAPTER NINETEENTH.

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" IT IS OF VITAL IMPORTANCE TO KEEP PUBLIC OPINION, ON THE SIDE OF SPECULATION, OR ENTERPRISE; NOTHING GREAT CAN BE ACHIEVED WITHOUT THIS IMPULSE TO ENTHUSIASM."—*Macculloch.*

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From the brief historical sketch Mr. John Fitch, an American candidate for the honour of having first navigated a vessel by a steam-engine, gave of his progress, it appears, that, as early as 1775, the same thought had also occurred to a Mr. Henry of Lancaster, (Pennsylvania); and that in 1778, the well-known Thomas Paine had mentioned a similar project to Andrew Ellicot, famous in that country, in his day, for his ingenuity.

To Fitch, as it had been to some of his predecessors, the project became a ruinous one. "I confess," says he, "that the first thought of a steamboat has been very unfortunate to me. The perplexities and embarrassments through which it has caused me to wade, far exceed any thing that the common course of life ever presented to my view." Fitch had made a model of his contrivance, and shown it to General Washington, who then recollected, that a Mr. Rumsey of Virginia had mentioned the same subject to him in conversation

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in the winter of 1784. But Fitch alleges that the model then exhibited by Rumsey to the General, was a boat to stem the current of rapid rivers, by means of wheels, cranks, and poles; a contrivance which, Fitch says, had been tried, many years before either his or Rumsey's had been thought of, on the river Schuyllkill, by a farmer near Reading, and the project failed. The inventions subsequently claimed by Rumsey, according to Fitch's statement, were improvements engrafted on his first scheme at a later period; and after Rumsey had heard of his (Fitch's) experiments, and for which he had ample opportunities; for as early as 1783, Fitch, on the Delaware River, had succeeded in moving a boat by paddles, which derived their motion from a steam-engine, and after some public trials, he presented a model and description of his apparatus to a philosophical society in Philadelphia, and also to Congress, in 1785.

Both Fitch and Rumsey were supported by associations of wealthy persons, who were to share in the profits of the respective schemes, and who advanced the money to make the experiments.

Rumsey's boat, about fifty feet long, with which he made some short voyages on the Potomac, in 1787, was propelled by a vertical pump in the middle of the vessel, by which the water was drawn in at the bow, and expelled at the stern, through an horizontal trunk in her bottom. The reaction of the effluent water carried her at the rate of three or four miles an hour, when loaded with three tons, in addition to the weight of her engine of about a third of a ton. The boiler held no more than five gallons of water, and needed only a pint of water at a time; and the whole machinery did not occupy a space greater than that

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required for four barrels of flour. The fuel consumed was not more than from four to six bushels of coals in twelve hours.

Rumsey's second project was to apply the power of a steam-engine to long poles, which were to reach the bottom of the river, and by that means to push a boat against a rapid current.

During these operations, Fitch and his friends, fancying that a profitable harvest might be reaped from the same invention, if put in operation in England, sent drawings of their apparatus to Bolton and Watt, with instructions to procure an English patent for it.

This coming to the knowledge of Rumsey's company, they forthwith began to contend with Fitch, even on the distant ground which he had selected as the scene of his future operations. Doctor Benjamin Rush, a polemical physician, entered the lists as a volunteer partisan of Rumsey's on this occasion, but with little credit to himself; the petty malignity of his opposition is the more extraordinary; for, although he is remembered as having been a hasty tempered, he is generally considered to have been a benevolent man.

"A certain Mr. Rumsey," says Dr. Rush to Dr. Lettsom, "from Virginia, strongly recommended by General Washington, lately produced a plan of a machine in our city, for improving the steam-engine, by reducing the fuel they consumed to one-eighth part of the usual quantity. This plan, it is suspected, has been copied, with a few trifling variations, by a person in this city, (equally known for plagiarism in philosophy, and a licentious opposition to the proposed constitution of the United States,) and transmitted to Mr. Bolton, of London, with a view of obtaining a patent for it. The only design of this letter is to re-

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quest you to suggest to Mr. Bolton, and to assure him that proper vouchers will be sent to him, which will irrefragably prove that the sole honour of the invention belongs to Mr. Rumsey, and that if any emolument arises from it, he alone is entitled to it."—"Mr. Rumsey," continues the partisan Doctor, "possesses a very uncommon mechanical genius—he has invented a boat, which sails by means of steam four miles an hour against the stream; he expects to increase the velocity of his boat to ten miles an hour by the application of the principles of his new steam-engine to the discovery:. his modesty is equal to his talents for invention. In behalf of his friends, (who are among the worthiest citizens,) I write to you in his favour. Your name and character are well known in our city—we look up to you to protect genius, to detect and defeat fraud, and to reward industry and integrity, in a country which has exhibited so many shining examples of them all in the promotion of science."

To neutralize the effect of this letter, the friends of Fitch also addressed a statement of their case to the same "great man." But the communication of Mr. Thornton (since a senator) is characterized by candour, and kind temperate feeling.

"I find," says he to Lettsom, "the company, of which Mr. Rumsey is principal, has procured a letter of introduction to thee from our good and worthy friend Dr. Rush. He pretends, Rumsey, I mean, to be the inventor of the steam-boat; I have, however, inclosed thee a couple of pamphlets, proving he got it from Mr. Fitch, of Philadelphia. These pamphlets were published before I had any thing to do in the affair, and on becoming acquainted with it fully, I purchased four

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shares, or one-tenth of the discovery. The boat is to be tried this evening, or to-morrow, and I will endeavour to give thee an account of it. Ours is moved with paddles placed at the stern, and worked by a small steam-engine."

Fitch did nothing in England, and the boat built, at the expense of his wealthy friends, on the Hudson, served only to make some unsatisfactory experiments, which did not even convince himself that the "paddle principle" was objectionable. But he had one consolation,—that if he had failed to obtain the confidence of the public, his opponent, Rumsey's experiments on the Potomac passed equally unheeded. The failure of both to carry either of their schemes into practice, in their case, as it had previously done in another, settled the dispute as to priority of invention in America.

Oliver Evans, a townsman of Fitch, and nearly about the same period, had been maturing a plan for using steam of an elasticity ten times greater than that employed in the condensing and atmospheric engines. And his proposal was further remarkable, as embracing a device to propel waggons on common roads, by a steam-engine instead of horses. "But all united," says he, "in condemning the scheme, except two gentlemen (one of whom was a projector himself), and indeed one, who has the name of a celebrated engineer, continued to oppose them for a long time after they were fully in operation *." In 1786, when

* One of his adversaries was a Mr. Latrobe, who uniformly opposed steam-boat projects, as well as those for steam-carriages. Fifteen years after this period, and three years before they were finally established, (unfortunately for his reputation,) he printed a report against their practicability.—We quote it as containing some *facts* respecting steam-navigation.—"After the American Revolution, a sort of mania

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Evans applied to the legislature of Pennsylvania, for an exclusive right to move land-carriages by steam, "they conceived me to be deranged," says he, "because I spoke of what they thought impossible, and they refused to grant the privilege I prayed for." The authorities of Maryland, to whom he next applied, with more wisdom than their neighbours, granted his petition, on the principle, that what he asked for could injure no man, and might cause him to produce something useful." But with all his perseverance, his reputa-

began to prevail, which, indeed, has not yet entirely subsided, for impelling boats by steam-engines. Dr. Franklin proposed to force forward the boat by the immediate action of the steam upon the water. Many attempts to simplify the working of the engine, and more to employ a means of dispensing with the beam in converting the libratory into a rotary motion were made. For a short time a passage-boat, rowed by a steam-engine, was established between Borden Town and Philadelphia, but it was soon laid aside. The best and most powerful steam-engine which has been employed for this purpose (excepting, perhaps, one constructed by Dr. Kinsey, with the performance of which I am not sufficiently acquainted), belonged to a few gentlemen of New York. It was made to act by way of experiment upon oars, upon paddles, and upon flutter wheels; nothing in the success of these experiments appeared to be sufficient compensation for the expense, and extreme inconvenience of the steam-engine in the vessel.

"There are, indeed, general objections to the use of the steam-engine for impelling boats, from which no particular mode of application can be free. These are—1st. the weight of the engine and the fuel.—2d. The large space it occupies.—3d. The tendency of its action to rack the vessel and render it leaky.—4th. The expense of maintenance.—5th. The irregularity of its motion, and the motion of the water in the boiler and cistern, and of the fuel vessel in rough water.—6th. The difficulty arising from the liability of the paddles or oars to break, if light, and from the weight, if made strong. Nor have I ever heard of an instance verified by other testimony than that of the inventor, of a speedy and agreeable voyage having been performed in a steam-boat of any construction."

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tion for practical knowledge, and his privilege to boot, Evans could not persuade any person of substance, to think so favourably of his steam-waggon, as to furnish him with the means to try one on a common road. And the drawings and descriptions of his scheme which he sent to England, to find a patron there, produced no better result.

The history of the result of another attempt to navigate by steam, which was made in Scotland, by Mr. Patrick Miller of Dalswinton, has been lately given to the public by his son *. Mr. Miller, in 1787, had published a description and drawings of a triple vessel, moved with wheels, and gave a short account of the properties and advantages of the invention. "In the course of his explanations, he suggested that the power of a steam-engine may be applied to move the wheels so as to give them a quicker motion, and consequently to increase that of the ship. It may readily be believed, that this hint of his intention to apply the power of steam to the wheels of his double and triple vessels, was not hastily thrown out. In the course of his various experiments on the comparative velocity of his vessels, with those propelled by sails, or by ordinary oars, which had given occasion to several interesting and animating contests for superiority, he had strongly felt the necessity of employing a higher force than that of the human arm, aided as it might be by the ordinary mechanical contrivances; and in this view, various suggestions were successively adopted, and in their turn laid aside. Thus, at one time it occurred to him, that the power of horses might be usefully

* "A short narrative of facts relative to the invention and practice of steam-navigation, by the late Patrick Miller, Esq. of Dalswinton, drawn up by his eldest son."—*Edinburgh Philosophical Journal*, 1824.

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employed; while at another, the aid of wind itself seemed to furnish the means of counteracting its own direct and ordinary operation. But among all the possible varieties of force, that of steam presented itself to his mind, as at once the most potent, the most certain, and the most manageable."

"In Miller's family there was at this time, as tutor to his younger children, Mr. James Taylor, who had bestowed much attention on the steam-engine, and who was in the custom of assisting Miller in his experiments on naval architecture, and the sailing of boats *. One day, in the very heat of a keen and breathless contest in which they were engaged with a boat on the Leith establishment, this individual called out to his patron, 'that they only wanted the assistance of a steam-engine to beat their opponents;' for the power of the wheels did not move the boat faster than five miles per hour. This was not lost on Miller, and it led to many discussions on the subject; and it was under very confident belief in its success, that the allusion was made to it in the book already mentioned.

"In making his first experiments, Miller deemed it advisable, in every point of view, to begin upon

* Mr. Miller, at various periods of his life, had embarked in many great schemes of improvement, and, among others, had expended large sums in experiments on the improvement of artillery and naval architecture. It was in the course of his speculations and experiments on the latter subject that he was led to think of devising some mode of constructing or propelling vessels in circumstances where the ordinary resources of the nautical art were insufficient or unavailing; among these, the construction of double and triple vessels, to be moved by wheels placed in proper situations, had occurred to him, as calculated to prove of essential service, and he accordingly built and equipped several vessels of this description."

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a small scale; yet a scale quite sufficient to determine the problem which it was his object to solve. He had constructed a very handsome double vessel, with wheels, to be used as a pleasure boat on his lake at Dalswinton, and in this little vessel he resolved to try the application of steam." On looking round for a practical engineer to execute the work, Taylor recommended a Mr. William Symington to his attention, whom he had known at school, and who had recently contrived a mode of applying the force of steam to wheel carriages; and he accompanied Miller to the house of a Mr. Gilbert Meason in Edinburgh, to see the model. Pleased with this specimen of Symington's ingenuity, he employed him, in conjunction with his friend Taylor, to superintend the construction of a small steam-engine, to work a double or twin boat. And in the autumn of the same year, the engine, which had brass cylinders of four inches in diameter, was fixed in the pleasure-boat on Dalswinton Loch. "Nothing could be more gratifying or complete than the success of this first trial, and while for several weeks it continued to delight Miller and his numerous visiters, it afforded him the fullest assurance of the justness of his own anticipation, of the possibility of applying to the propulsion of his vessels, the unlimitable power of steam. On the approach of winter, the apparatus was removed from the boat, and placed as a sort of trophy in his library at Dalswinton, and is still preserved by his family, as a monument of the earliest instance of actual navigation by steam" in Great Britain.

Symington, in the succeeding year, was again commissioned by his patron to try the experiment on a greater scale; a double vessel, sixty

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feet long, was to be fitted with an engine and revolving paddles, suited to the supposed exigencies of the case. The engine and machinery were constructed at Carron, and in the course of six months the vessel was ready to be put in motion. In December, 1789, it was taken into the Forth and Clyde Canal, and in the presence of a vast number of spectators, the machinery was put in motion. "This second trial promised to be every way as prosperous as the first. It happened, unluckily, however, that the revolving paddles had not been made of sufficient strength, and when they were brought into full action, several of the float-boards were carried away, and a very vexatious stop was, for that day, put to the voyage. The damage was repaired, and on the 25th of December, the steam-boat was again put in motion, and carried along the canal at the rate of seven miles an hour, without any untoward accident, although it appeared evident that the weight of the engine was an overburden for the vessel (her planking being only three quarters of an inch thick), and that under such a strain it would have been imprudent to venture to sea. The experiment, however, was again repeated on the two following days; and having thus satisfied himself of the practicability of his scheme, he gave orders for unshipping the apparatus, and laying it up in the storehouses of the Carron Company."

"It may naturally occasion surprise and disappointment," continues his son, "that I should have to terminate here, this account of my father's experiments on steam-navigation; that he did not follow up these prosperous and decisive trials of its efficacy, with the same spirit and perseverance, which had been so conspicuous in many other instances, must for ever be matter of regret to his

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family, as it was to himself in the latter years of his life." The fact, however, was, "that he had to complain of the enormous expense in which he had been involved; and I may be permitted to add," continues his son, "that by this time my father, in the prosecution of his various schemes of a purely public nature, and without the slightest chance or expectation of reimbursement, had expended upwards of thirty thousand pounds." And, being by this time ardently engaged in agricultural pursuits, his attention was more easily turned from the objects of his former speculations, than those acquainted with his character would have been prepared to anticipate.

"Be that as it may, it cannot be disputed, that in point of fact he had fully established the practicability of propelling vessels of any size, by means of wheels or revolving paddles, and of adapting to these the powers of the steam-engine, although, in the subordinate details of execution, great room remained for minor improvements."

"Of my father's peculiar and undoubted merits as an inventor, I have," continues his son, with a pardonable partiality, "endeavoured to give a fair and unvarnished account; and of the reality of that invention, as carried into actual practice in the years 1788 and 1789, no demonstration more unequivocal can be desired than that, with his few but most satisfactory experiments, the prosecution of this momentous discovery remained suspended for many years, in a state of inactivity and neglect, till at a period comparatively recent, it was revived in America, and in this country, by persons who can be proved to have derived their first lights from the experiments at Dalswinton and at Carron. But I have felt no other desire than to record the facts immediately connected

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with my father's operations, and to establish the priority of his claims to the credit of having originated, and carried into practical execution, an improvement in the nautical art, by far the most important of which the present age has to boast; and the ultimate effects of which, on the future intercourse of mankind, the most sanguine imagination would attempt in vain to predict."

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CHAPTER TWENTIETH.

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" THE BANE OF IMPROVEMENT IS A HOPELESSNESS OF ITS POSSIBILITY—ANOTHER BANE IS THE WANT OF JUDGMENT TO SEE WHERE THE DEFECT LIES, AND PRACTISING ON THE WRONG PART."—*Scott.*

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THE loss of power from the reciprocation of the motion of the massive parts of the condensing engine, was greatly magnified, by all those whose attention had been given to the subject. Avoiding this supposed evil, was one of the advantages expected to arise from the invention of a rotary engine; but the steam-wheel described by Mr. William Cook in 1787, is still less adapted to practice than Watt's, and it merits a description only as being the first of a class. The wheel *a*, has valves or flaps, *c d e*, hung upon its circumference and opening only in one direction; the half of the wheel is enveloped in a case made steam and air-tight; *f*, is a pipe leading from the boiler, *g*, a pipe leading to the condenser, *h*, a piece of wood which shuts the valves as they come into contact with it; and those which have passed the condenser pipe are shut by the horizontal part of the casing; as the steam issues through the pipe *f*, it presses forward the valves *c d e*, towards the condenser

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pipe, and the wheel is made to revolve as the flaps or valves in the other parts of the circumference enter the steam-tight casing. Cook made his flaps to have an area of thirty-six square inches, and thought his wheel would be forced round with a force equal to five hundred and thirty-one pounds!

The next attempt to produce a direct rotary movement, was made by a man second to no one of his time for the number, originality, and usefulness of his inventions. Joseph Bramah was the eldest son of a small farmer, and followed in his youth his father's occupation. His hours of relaxation from the business of the farm were, however, generally spent in attending a neighbouring blacksmith's shop, between whose tenant and himself was shared the merit of several ingenious pieces of mechanism. An accidental lameness in his ancle unfitting him for agricultural labour, he was apprenticed, in his sixteenth year, to a carpenter and joiner; at the expiration of his servitude he went to London in search of employment, and there he soon established himself as a master in his trade. His extended means enabling him to indulge his mechanical taste, he quickly became known as a man possessing a fine invention, as well as great executive skill. The admirable lock which bears his name, was the most perfect mechanism of its kind that had ever been produced, and to this day it is unrivalled for safety, durability, elegance and simplicity. The pressure of fluids in every direction, had been commented on, from the time of the Greek philosophers downwards; the disparting of mountains, and the heaving of valleys, were explained by men learned in hydraulic action, as produced by this property of fluid matter; the form of the model

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by which they explained the principle, is still retained, and known as the hydrostatical paradox; and who has not admired the beautiful toy? It was Bramah who first called the latent power into exertion, and in applying it to the purposes of life produced a machine, by the aid of which, with the puny force of a child's arm, he could tear up trees by the roots, and crush bars of iron as if they were pieces of wax beneath it. If, as an invention for developing power, it is equal in importance to the steam-engine, it far exceeds it in value as a machine of society: for its use is limited by no circumstances of a local nature, nor depends on a consumption of any extraneous substance whatever; two small pipes, each fitted with a piston and a little water, which for years needs no replenishing, gives to an ordinary man in all situations the strength of a giant*.

* JOSEPH BRAMAH, one of the greatest mechanics England has produced, was born on the 13th of April, 1749, at Stainborough, in Yorkshire: he exhibited, at a very early age, an unusual talent for mechanical contrivances, and succeeded, when he was quite a boy, in making two violoncellos, which were found to be very tolerable instruments; and in cutting a single block of wood into a violin, chiefly by means of tools, which were forged for him by a neighbouring blacksmith, whom, at a subsequent period of his life, he induced to assist him in London as his principal workman. The best history of Bramah's future life would be a history of his inventions, but our limits will only permit our giving a bald catalogue of a few of them. In 1784 he produced his celebrated *lock*, the peculiar character of which depends on the arrangement of a number of levers, or sliders, to preserve, when at rest, a uniform situation, and to be only pressed down by the key, to certain unequal depths which nothing but the key can ascertain—the levers not having any stop to retain them in their required situation, except that which forms part of the key. He added afterwards some modifications for allowing the key to be varied at pleasure. The report that one of these locks had been readily opened, before a Committee of the House of Commons, by

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In his designs for a rotary steam-engine, he was associated with a Mr. Dickenson, but Bramah's genius is apparent throughout; his first scheme will readily recall the general appearance of his

means of a common quill, was a gross misrepresentation of the fact; the quill having, in reality, been previously cut into the required shape from the true key, an experiment which was only made to show the perfection of the workmanship, and the very small force required to overcome the resistance when properly applied. It has been subsequently stated, that one of these locks had been in use for many years, and had been opened and locked not less than four hundred thousand times, and apparently was as perfect as when it was first constructed. His *watercock*, or valve, allowed the fluid a more uninterrupted passage through it, than those did which were on the common construction. His "*rotative principle*" will be understood by supposing water to be employed instead of steam in the machines described in the text—a similar idea was thrown out by Ramelli, Cavelleri, Amontons, and others. The invention, however, for which he will probably be best known to posterity, is his *hydraulic press*, in which the smallest imaginable force is capable of holding in equilibrium, the greatest imaginable pressure. This is one of the most admirable machines in the whole compass of the arts; some envious blockheads call it Pascal's Machine, and in their descriptions they almost say that Pascal invented it; but that ingenious philosopher has about as much claim to this great honour as the old woman who first discovered her beard and her wrinkles, in her polished pewter platter, had to be considered as the inventress of the Newtonian telescope. Before Bramah's time, "Bonifaces were obliged to trudge to the cellar for every drop of the beverage they measured out to their customers; or have their barrels placed in waiting on the same level with their parlour: in most states of weather, this was a hazardous position—in some states it was positively injurious." Bramah, by his elegant *Beer Machine*, enabled them to pump up into the measure in the bar, the fermented juice contained in various casks in the cellar—it is now in general use. His *steam wheels* and *valves* have also been noticed in the text.

Machinery for *smoothing surfaces* was another of his elaborate and beautiful specimens of mechanism. It was erected at the National Arsenal at Woolwich with perfect success; the axis of the principal shaft was supported on a piston in a vessel of oil, which diminished the friction considerably, and

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lock; a hollow cylinder *a*, is divided in the middle of its length, by a partition *b*, to which the axle is fixed; *c*, a piston fixed on its circumference; *d e* apertures made on each side of the piston, *d* com-

could be accurately regulated by means of a small forcing pump. He introduced also a mode of *turning spherical surfaces*, either convex or concave, by a tool moveable on an axis perpendicular to that of the lathe: and fixing a curved tool in the same position he cut out *concentric sheels*. He also described machinery for making *paper in large sheets*; for *printing by means of a roller*, composed of a number of circular plates, turning on the same axis, each bearing twenty-six letters, capable of being shifted at pleasure, so as to express any single line by a proper combination of the plates. This was put in practice to number bank-notes, and enabled twenty clerks to perform the labour which heretofore had required one hundred and twenty. His scheme for *making and holding pens* is well known; and his project for *main pipes* in 1812, was, however, in some parts, more ingenious than practicable. In describing them, he mentions having employed a hydrostatic pressure equal to that of a column of water twenty thousand feet high, (about four tons for every inch). He also asserts that he can form five hundred tubes, each five feet long, capable of sliding within each other, and of being extended, in a few seconds, by the pressure of air forced into them, to a length of two thousand five hundred feet; with this power he proposed to raise wrecks, and regulate the descent of weights. His improvements in *wheel carriages* consisted in fixing each wheel to a separate moveable axis, having its bearings at two distinct points of its length, but loosely inclosed between those points in a cylinder filled with oil; in another, opposite wheels were to be fixed to the same axis, though with a power of turning very stifly round it to lessen the lateral motion in rough roads; and he suggests *pneumatic springs*, formed by pistons sliding in cylinders, as a substitute for springs of metal; latterly, he improved the machines for *sawing stones and timber*, and suggested some alterations in the construction of *bridges and canal locks*. His last illness was occasioned by a severe cold, taken during some experiments on the tearing up of trees in Holt Forest. He died on the 9th of December, 1814.

Bramah was a sincere and unostentatious follower of the precepts of Christianity—his conversation was animated, and in its general tone and bias might be characterized as polemi-

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municating with one half of the cylinder and condenser, and *e* with the other aperture and the boiler; *f g* sliders, which, by means of the rotation of an eccentric wheel, *x*, may be moved inwards to press against the cylinder *a*, or withdrawn into the recesses *h i*, so that the piston in its revolution can pass freely over them; it is so arranged, that at the moment one slider is pressed against the surface of the inner cylinder, the other slider is drawn into its recess. In the figure, the slider *g*, is pressed upon the revolving cylinder, and the steam enters through the aperture *e*, between *g* and *c*, while all the rest of the space within the drum is open to the condenser through the aperture *d*, the piston therefore is urged towards *f*, and over it; when the slider *f* is moved inwards, until it comes into contact with the cylinder *a*, at the same moment the slider *g* is drawn into its recess, until the steam which flows into the space between *f* and *c*, has urged the piston beyond it; it is then again pressed upon the hollow cylinder, and the other slider is drawn outwards; all the parts are then in the position shown in the figure, and the piston has made a complete revolution, and is commencing its second.

cal: to much facility of expression he added the most perfect independence of opinion—he was a cheerful, benevolent, and affectionate man—neat and methodical in his habits—and knew well how to temper liberality with economy; and, greatly to his honour, he often kept his workmen employed, solely for their sake, when the stagnation of trade prevented him from disposing of the products of their labour. As a manufacturer he was distinguished for his promptitude and probity, and he was celebrated for the exquisite finish which he gave to his productions. In this excellence, which he was the first to introduce, so he continued, as a model to be unrivalled. At his death he left his family in affluent circumstances, and his manufacturing establishments have, since his death, been continued by his sons.—*Memoir by* Dr. Brown.

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The two following figures, 2, 3, will be understood from inspection; sliders or valves *a b*, move backwards or forwards in a hollow cylinder *c*, which revolves within a fixed cylinder *d*; within this fixed cylinder is a circular division *e*, which at the point *f*, is brought into contact with the revolving cylinder, and by this means makes a division between the two halves of the cylinder. The pipe *g*, connects the fixed cylinder with the boiler, and opens a passage from it to the pipe *h* with the condenser, one of the sliders will thus always be interposed between the pipes *g* and *h*; a vacuum being made in the condenser, and steam permitted to flow into the cylinder, it will act to press the slider *a* towards the pipe *h*, and as it comes into contact with the inner division *e*, it is pressed into the revolving cylinder; but during the revolution, the other slider, by coming into contact, has been moved outwards so as to bear against the outer cylinder, and be interposed between *g* and *h*, and is pressed forward into the vacuous space, by the steam from the boiler, until it comes into contact with the division *e*, and passes the condenser-pipe; during its progress to this point, the other slider has again been pressed outwards, and forms the partition between the steam and the vacuum as before.

In the third figure, the inner division *e* is dispensed with, and the revolving cylinder is brought into contact with the outer or fixed cylinder. The sliders are formed and placed in the same manner as in the previous design, and are also moved backwards and forwards, by their opposite ends coming into contact with the outer cylinder.

Symington's combination of the parts of Newcomen's engine was a clever attempt to reap the benefit of an invention, and avoid the claims of its au-

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thor. This apparatus was a very long cylinder, having its lower end turned like an elbow, in a horizontal position. The upper side of the steam piston was open to the atmosphere, the inner, or air piston had a separate rod, which worked through a stuffing box (so as to be air-tight) at the bottom, and was attached to a horizontal lever, which was moved by being fixed to a rod hanging from the balanced lever. The steam piston never fell below the steam-pipe opening, and the air piston never rose above it; and if the stroke of the upper piston was forty inches, that of the under was between five and six inches; a steam pipe and valve was fixed about the middle of the vertical cylinder, and an exhausting pipe and valve also entered it nearly at the same place; this was carried into the horizontal part, or elbow, and a valve formed a communication between it and the lower part of the cylinder; and a jet of water was introduced as in Watt's condenser, and to perform the same office. An air valve, opening outwards, was fixed at the lower part of the cylinder; and the lower piston had a similar valve opening upwards. Supposing both pistons to be at the highest limit of their stroke, vapour flows through the steam valve, and fills the space between the pistons. The steam valve being shut, and the exhausting valve opened, the jet playing in the elbow part condensing the vapour which rushes in from the cylinder, forms a vacuum beneath, in the space between the pistons. The upper piston being open to the atmosphere is pressed downwards, while, at the same time, the lower piston being attached to the balanced lever, is also drawn down, and in its descent expels all the air and water beneath it through the air valve into the atmosphere, or hot-water cistern. The steam and

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air pistons having reached the limit of their strokes, the exhausting valve is closed, and the steam valve opened; the steam is again introduced between the two pistons, and this allows the counterpoise to act to draw the steam piston to the top of the cylinder, and to press the air piston into its first position.

So palpable an imitation was not calculated to effect the object of which Symington was in pursuit, and the use of one or two of these engines which had been erected was given up by their owners, rather than risk a comparison being drawn in a court of law, between this and Watt's exquisite mechanism.

The modification of Savery's apparatus, adopted by Mr. François, a professor of philosophy at Lausanne, in the draining of a morass, between the lakes of Neuchatel, Bienne, and Morat, resembles Gensanne's, (p. 199), but as a whole has more practical merit. (See figure marked FRANÇOIS.) The lower end of the suction pipe, *a*, is immersed in the water *b*, a valve in the bottom of the recipient *c*, *d* cock and pipe from boiler; *e* a lever with two tappets between a lever attached to the steam cock plays; *f* a pipe from the trough *g*, which has a valve opening upwards, and moved by the lever *e*; *h*, the eduction pipe and cock, *m* a rod, which acts between two tappets fixed on the lever *i*, which is jointed to the balanced trough *k*. When the recipient is nearly filled with water (as in the figure), the steam and eduction cocks are open, and the water is forced through *m* into the balanced trough, which is nearly filled; the end *o* preponderates, and the water is emptied into the trough *g*.

The fall of the balanced trough raising the end of the lever *i*, this shuts the eduction cock; at

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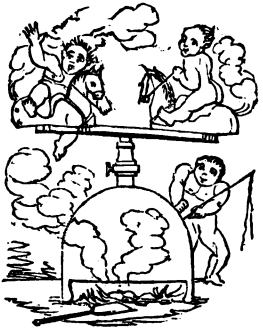
the same time the lever *e* shuts the steam cock, and opens the small cock in the pipe *f*; this allows a jet of water to fall into the recipient to condense the steam, and a vacuum being made in it, the water from the morass rises through the suction pipe, and raising the valve fills the recipient. This is a very quick operation, for as soon as all the water has been emptied from the trough, the counterpoise *n* restores it to its first position, and this movement makes the levers restore the cocks to their first position. The eduction and steam cocks are therefore opened, and the steam from the boiler forces up the water as before.

The next contrivance for a rotary motion, differing widely from those by Bramah and Watt, is



described by Langsdorf, a German author, as the invention of one Kempel, his countryman; it will, however, be recognised as of the same family with that which has been described as Hero's toy.

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The steam rising from a boiler through a vertical pipe, flows into a horizontal tube, which revolves on the vertical one, as on a pivot, the vapour issues from two small orifices made in the side, at each end of the moveable arm, and its reaction on the air produces a rotary motion *.

Mr. James Sadler, of Oxford, in 1792, practised a similar method, but with the difference of making steam, issuing with great velocity from a pipe *a*, re-act upon the *air* inclosed in a casing *c*. Sadler also reversed the motion, by introducing a jet of cold water into the pipe; the air then had a tendency to enter it, and to carry it round its axis.

The economy of the machine is greatly improved by the water produced by the injection, and condensation being made to perform a mechanical office by falling into the reservoir of a Barker's mill; a hint that might, in a great many other combinations, be acted upon with advantage.

Watt in one of his specifications described a combination, by which the alternate action of the pistons of two single impulse engines, on the same cranked axis, would produce a motion sufficiently uniform to be applied with advantage as the first mover of machinery, where the effect of what was called the neutral stroke might be inconvenient or detrimental. His subsequent invention of the double impulse engine left nothing on this head to be wished for.

But the spread of the cotton and woollen manufacture, and the practice which was now becoming prevalent, of driving corn-mills by steam, created a great demand for engines, in which this power was the motive agent. Strong prejudices,

* *Handbuch der Mechanik*, Altenburg, 1794.

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however, at the same time, continued to operate to exclude Watt's perfect mechanism from being employed in cases where its use was calculated to afford the most signal advantage. This necessarily turned attention to produce the same continuity of impulse, by introducing the double impulse into Newcomen's apparatus. The most meritorious of the schemes, to accomplish this matter, which had any pretensions to originality, was that of Mr. Francis Thompson, of Ashover. He placed one cylinder, *a*, in an inverted position over another, *b*, and connected their two pistons, *c*, *d*, with the same rod *e*; which itself was attached to the great lever *f*; *g*, a pipe conveying steam from the boiler to the inverted and lower cylinders, having valves to shut it off, or admit it to each, or both, at pleasure; *h*, the injection pipe, proceeding to both cylinders from an elevated cistern, with the usual cocks to regulate, or stop its flow; *i*, air and water valves opening outwards.

If the engine is supposed to be ready to commence a stroke, the pistons will be in the position shown in the figure. The steam valve of the inverted cylinder is open, and its injection valve is shut, but the steam valve of the lower cylinder is closed, and its injection cock open; a vacuum is, therefore, existing below the lower piston, and the steam lays on the upper. It will be obvious, that as the pressure of the steam on this piston balances the upward pressure of the atmosphere on its opposite side, the piston is in equilibrio; but as there is a vacuum beneath the lower piston, the air's weight presses that downwards into its cylinder, drawing the upper piston along with it; this makes the downward stroke. The position of the valves being then reversed, the steam is prevented from flowing into the upper cylinder,

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and a jet falling into it from the injection pipe, forms a vacuum above the piston, and the pressure of the atmosphere on its opposite side forces it upwards, while steam being admitted to flow into the lower cylinder, allows the piston placed in it to rise in equilibrio; this forms the upward stroke; and when the valves are again reversed, the downward stroke commences as before. Some machines of a large size were erected on this model, to move the machinery of woollen and cotton manufactories at Nottingham and Manchester, which, as far as uniformity of motion went, answered the expectations of their owners; but their consumption of fuel was excessive. The same variety of engine was also constructed with a separate air pump and condenser, but these additions were plagiarisms, which deservedly brought those who used them into a court of law, where they never failed receiving the punishment of pirates. A similar effect was produced by placing two cylinders at opposite sides of a toothed-wheel, which received an alternate movement from working in racks made on the piston rods; and the reciprocating motion was converted into a rotary one by a crank and a fly wheel. This was nearly Watt's idea, and getting rid of the counterpoises is not the least of its merits. Some were also erected with condensers and air-pump; but the same fate followed these attempts, that had fallen on their predecessors in the same practice.

Whatever were the reasons which induced Rumsey to desist from his attempts in America, to move a boat by a steam-engine, they were not sufficient to convince him that better success could not attend a trial of a similar mechanism on an English river; for, subsequently, he even suc-

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ceeded in inducing a wealthy American merchant, then residing in London, and some equally sanguine natives, to disburse the expenses of another experiment. Rumsey had spent two years, nearly, in preparations, and was on the eve of putting the last hand to his steam-boat when he died. The parties, however, who were associated with him in the enterprise got the vessel afloat, in February, 1793, and sailed her many times on the Thames against wind and tide, with the speed of four knots an hour. The propelling machinery was on the same principle as that of the boat Rumsey constructed on the Potomac.—"The pump, two feet in diameter, wrought by a steam-engine, forced a quantity of water up through the keel; the valve was then shut by the return of the stroke, which at the same time forced the water through a channel or pipe, about six inches square, (lying above, or parallel to, the kelson,) out at the stern under the rudder, which had a less depth than usual, to permit the exit of the water. The impetus of this water forced through the square channel against the exterior water, acted as an impelling power upon the vessel."

The project of Genevois, to impel boats by an oar, formed after the model of those exhibited by nature, was revived by the Earl of Stanhope * in

* Charles Stanhope, third Earl of Stanhope, was born at Chevening, Kent, in August 1753. In his ninth year he was sent to Eton, and at this early age he began to give proofs of his strong bias to mechanical and mathematical pursuits. In his nineteenth year he was removed to Geneva, and placed under the tuition of Le Sage; and, a few months afterwards, he gained a prize, offered by a foreign national Academy, for the best paper, written in French, on the construction of the pendulum.

The Earl was the author of a great number of inventions and improvements in the arts and philosophy. Among those

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1795, the paddles made to open and shut like the feet of a duck, were placed under the quarters of the vessel: the engine which gave them motion was of great power, and acted on machinery that

which attracted most attention were his *electrical experiments;* his scheme for *securing buildings from fire;* a *machine for solving problems* in arithmetic; a mode of *roofing houses;* and a *kiln for burning lime;* a *steam-boat;* a *double inclined plane* for remedying the inconveniences attending canal locks. This was suggested to the Earl while he was engaged in forming a canal in Devonshire, the line of which he surveyed himself, and during this employment he carried for days the theodolite on his own shoulders. Experiments on *stereotype printing;* an esteemed printing press, which bears his name; a plan for *preventing forgeries,* in coin and bank notes, &c. In putting his ideas into practice he was assisted by Mr. Varley, one of the most expert practical mechanics of the day.

But numerous and important as his labours were to the arts, they were even, in a public view, exceeded in importance by the impulse which his patronage gave to mechanical artists. His purest pleasure seemed to consist in bringing them, and their productions, before the public; and in furtherance of this design he spent a large portion of his ample fortune, and almost the whole of his thoughts and time.

Whatever view different men might take of the soundness or tendency of the political opinions of Earl Stanhope, all were convinced that they sprang from the honest conviction of his mind, uninfluenced by the most remotely interested motive, for he uniformly declined place, pension, or additional honours. If his projects, both political and mechanical, were occasionally considered to be impracticable, they were neither sordid nor selfish. His speeches in the House of Lords, and in public, on whatever topic, were full of ingenious and recondite matter—acute in argument—perspicuous in arrangement and language, and not deficient in force and spirit. But it was often as difficult to answer them, as it was to coincide with them; for he seldom adapted his opinions to the state of public affairs, but reasoned from some abstract standard of moral or political right, that was seldom in accordance, either with the principles of party, or with state expediency. He was sometimes eloquent; but as his illustrations not only wanted elegance, but were often remarkable for their racy eccentricity, and as there was a certain quaintness in his manner, the effect was often quite ir-

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produced a horizontal stroke; but, notwithstanding the diminution of surface which was produced by the conformation of the oars, the re-action of their being drawn backwards was so great, that the flat-

resistible, even to producing laughter from the guarded and studied gravity of the incumbent on the woolsack. His Lordship's activity and perseverance were amazing; for notwithstanding the multiplicity of his projects and experiments, he assuredly was profoundly learned in every thing that regarded the constitution and ecclesiastical polity of his country; and when on these subjects he might be pardoned the exclamation—"That he had taught the judges law, and the bishops religion." When questions arose which required a practical knowledge of the exact sciences, or their application to the arts, if he were not the only man, he was at least the ablest one, in the House, to expound, discuss, and decide them: on such occasions he acted with great judgment.

Earl Stanhope married Hester Pitt, a daughter of the great Earl of Chatham, whose political principles he venerated with a feeling little removed from idolatry; and in the early part of his public career he acted cordially with his brother-in-law, Mr. Pitt. But the circumstances which induced that consummate statesman to alter his opinions, had not the same effect on the Earl, and their political connexion was dissolved. On this separation taking place, a domestic schism was produced at Chevening, by the Earl wishing his children to devote themselves to acquire some *useful calling as he had done*, by which, when the fatal day of public calamity came, and of which he imagined that he foresaw the rapid approach, they might secure independence by their own personal ingenuity and labour.—"Charles Stanhope," his Lordship said, "as a carpenter, a blacksmith, or a millwright, could in any country, or in any times, preserve his independence, and bring up his family in honest and industrious courses, without soliciting either the bounty of friends, or the charity of strangers."—But his family preferring the patronage of their uncle, the minister, to the protection of the paternal roof, the Earl declared that, as they chose to be saddled on the public purse, they must take the consequences. They were not, therefore, mentioned in his will, but they were entitled to certain sums by a marriage settlement, and the present Earl succeeded to the family estates, worth about twelve thousand pounds a year.

Earl

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bottomed vessel with which the experiment was made, in Greenland dock, did not move with a velocity exceeding three miles per hour. It has been mentioned that paddle-wheels were suggested to his lordship, during these trials, as more likely than the duck-foot oars to produce the required speed; but the hint, though meant to be a broad one, was thrown away upon the noble projector *.

In the succeeding year, 1797, Chancellor Livingston also made some experiments to build a steam-boat on the Hudson, with the assistance of a person of the name of Nisbet, who went from England to America †. And Mr. Brunel, who has

Earl Stanhope was singular in his dress and person, and his plain, unaffected, amiable manners, were also considered to be singular for a man of his high rank and connexions; but they conciliated affection in many cases approaching to devotion, and his general integrity commanded cordial respect. He was a considerate and kind landlord, an ardent friend, and his purse and influence were ever open to the claims of the helpless and the poor. He died in December, 1815.

* Mr. Robert Fulton, an American, then living at Torbay, in Devonshire, had some correspondence with Lord Stanhope, on the subject of moving ships by a steam-engine. The drawings he made of his apparatus, are dated in 1793; and his proposal to submit them to Lord Stanhope for his inspection, appears from his Lordship's reply, to have been made previous to October 1794. At the time, and for many years after, Fulton had gone no further than drawing his machinery.—*Colden's Memoir of Fulton.*

† When the Chancellor, in 1797, applied to the legislature of the State of New York, for a privilege to navigate boats by a steam-engine, the project was considered so visionary, that when the matter was under consideration, the gentleman who introduced it says, "the wags and the lawyers were generally opposed to it, and I had to encounter all the jokes, and the whole of their logic. One main ground of objection was, that it was an idle and whimsical project, unworthy of legislative attention. It was a standing subject of ridicule, and whenever there was a disposition in any of the younger members to indulge a little levity, they would call

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since so greatly distinguished himself as an engineer, was associated with the projectors on this occasion. The engine was found incapable of driving the boat through the water*.

The steam-wheel of Dr. Cartwright is similar to that of Watt. He attached three pistons to the revolving axle; two pipes of communication with the condenser, and two with the boiler, were placed in pairs at opposite sides of the circumference of the cylinder, and instead of one abutment-valve, as in Watt's scheme, he introduces two. The mode of action of both is the same.

In arranging the parts of the condensing engine, Cartwright dispensed with the beam or working lever, and gave what he considered to be a more convenient form to the condenser than Watt had done. Producing condensation, by bringing the steam into contact with a cold *metallic surface, instead of a jet of cold water*, Cartwright intended that the water formed from the condensed steam, should be returned incessantly into the boiler, and that in many cases a great saving could be made by using alcohol instead of water, as that could be condensed and rarefied alternately, without admixture with the condensing medium. On this account his engine was adapted to be introduced into distilleries, with great economy of fuel, as the alcoholic vapour, in the process of

up the steam-boat bill, that they might divert themselves at the expense of the project and its advocates.

"Notwithstanding these sallies, the bill was passed, containing the condition that the Chancellor should within a twelvemonth, produce a vessel, the mean rate of whose progress should notjbe less than four miles an hour. The experimental boat of thirty tons burden, propelled by a steam-engine, being, on trial, found incompetent to fulfil the condition of the grant, it became obsolete, and Livingston gave up his project."—*Colden.*

* *Quarterly Review*, vol. xix. p. 354.

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rectification, might be introduced under the piston, and after raising it by its elasticity, be condensed, and from the lower temperature required for converting the spirit into vapour, having a tension equal to balancing the weight of the atmosphere, there should be, on this account alone, a smaller consumption of fuel under the boiler. The piston *x*, (in the engraving marked CARTWRIGHT,) moving in a cylinder *a*, has its rod prolonged downwards, terminated by another piston *c* working in a small cylinder *b*, and which forms a continuation of the larger cylinder *a*. The piston *x* has a valve (shown on a larger scale in the figure) by which a communication is always opened between the cylinder, either above or below the steam piston, with the condenser *b*; *i*, is the steam valve; *h*, steam pipe from the boiler; *l*, a horizontal bar or lever, connecting the piston rod with the wheels *o p*, which give motion to the pinion *k*, placed on the axis of the fly-wheel *s*; *g*, an air valve, which is opened and shut by the fall or rise of a ball which floats on the surface of the water; during the descent of the piston *x*, by the steam issuing through *i*, the air and water which had fallen from the condenser below the piston *c*, was pressed up the pipe *e*, into the box *g*; when the piston *x* has nearly reached the bottom, the tail of the valve *x*, coming into contact with the the bottom of the cylinder, the valve is lifted up at the same time that the steam valve *i*, is closed by the fall of the lever *l*. A communication is thus established between the space above the piston and the condenser; and the piston *c*, being at the bottom of the cylinder *b*, all the air and water which it contained has been pressed up the pipe *e*, these being prevented from returning into the condenser by a valve (not shown in the

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engraving) which opens upwards, where the condenser pipe joins to it. The vacuum being thus both above and below the piston, the force which has been accumulating in the fly-wheel *s* during the descent of the piston, has accumulated a sufficient energy to draw the piston *x* to the top of the cylinder, and the rise of the lower piston forming a partial vacuum beneath it also, the water and air from the condenser rise through the pipe which connects it with the lower cylinder; the valve *x* being then pressed down and *i* opened, the steam urges the piston downwards a second time.

Some small single engines on this construction, erected near London, did not fulfil the expectations of their accomplished inventor*; the condensa-

* EDMUND CARTWRIGHT, D.D., was born in 1743, in Nottinghamshire, at Marnham, an estate which had long been in possession of his family. He was the youngest of three brothers, all of whom were remarkable men. His second brother, Captain *William Cartwright*, a man of great enterprise and energy of character, after a residence of sixteen years on the Coast of Labrador, returned to England in 1792, and published his journal, which gave the first authentic account of the Esquimaux nations. His elder brother, Major *John Cartwright*, was for forty years distinguished as an enthusiastic and persevering advocate for what is called Parliamentary Reform; and notwithstanding the many turbulent scenes in which he appeared in public, in domestic life he was exemplary as an amiable, affectionate, and benevolent man; as a political leader he was truly consistent, and even his enemies have borne testimony to his being perfectly disinterested.

Edmund, the younger brother, being destined for the church, was placed under Mr. Clarke, of Wakefield, and the celebrated Dr. Langhorne. He afterwards studied at Oxford, where he was early distinguished for his literary attainments, and was elected a Fellow of Magdalen College. On entering the church, he retired to a small living in the gift of his family, where he discovered the application of yeast as a remedy in putrid fevers, and became known as a

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tion by contact was not sufficiently rapid, and the action of the valves was found not to be so precise as was desirable.

A double engine on the same plan turned a mill

poet. His legendary tale of "Armine and Elvira" was greatly admired for its pathos and elegant simplicity. His "Prince of Peace," in a loftier style of composition, also excited much attention at its appearance. He married in 1772, and afterwards went to reside at Doncaster, but still assiduously continued his literary labours. Between 1774 and 1784, he was one of the principal contributors to the "Monthly Review." The origin of his invention of *weaving by machinery*, instead of manual labour, has been minutely detailed by himself, in a letter written to Mr. Dugald Bannatyne, of Glasgow.

"Happening to be at Matlock in the summer of 1784, I fell in company with some gentlemen of Manchester, when the conversation turned on Arkwright's spinning machinery. One of the company observed, that as soon as Arkwright's patent expired, so many mills would be erected, and so much cotton spun, that hands never could be found to weave it. To this observation I replied, that Arkwright must then set his wits to work to invent a weaving machine. This brought on a conversation on the subject, in which the Manchester gentlemen unanimously agreed, that the thing was impracticable, and in defence of their opinion, they adduced arguments which I certainly was incompetent to answer, or even to comprehend, being totally ignorant of the subject, having never, at that time, seen a person weave. I controverted, however, the impracticability of the thing, by remarking that there had lately been exhibited in London an automaton figure which played at chess; 'now you will not assert, gentlemen,' said I, 'that it is more difficult to construct a machine that shall weave, than one which shall make all the variety of moves which are required in that complicated game?'

"Some little time afterwards, a particular circumstance recalling this circumstance to my mind, it struck me that, as in plain weaving, according to the conception I then had of the business, there could be only three movements, which were to follow each other in succession, there would be little difficulty in producing and repeating them. Full of these ideas, I immediately employed a carpenter and smith to carry them into effect. As soon as the machine was finished I got a weaver to put in the warp, which was of such materials as

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at Wisbeach, but was taken down, and afterwards erected at Woburn, where it was in a few years allowed to fall into decay. The defective condensation was much more apparent in this than in the

sail cloth is usually made of. To my great delight, a piece of cloth, such as it was, was the produce: as I had never before turned my thoughts to any thing mechanical, either in theory or practice, nor had ever seen a loom at work, or knew any thing of its construction, it will readily be supposed that my first loom must have been a most rude piece of machinery. The warp was placed perpendicularly, the reed fell with a force of at least half a hundred weight, and the springs which threw the shuttle were strong enough to have thrown a Congreve rocket; in short it required the power of two powerful men to work the machine at a slow rate only for a short time. Conceiving, in my great simplicity, that I had accomplished all that was required, I then secured what I thought a most valuable property, by a patent in April, 1785. This being done, I then condescended to see how other people wove, and you will guess my astonishment when I compared their easy modes of operation with mine. Availing myself, however, of what I then saw, I made a loom, in its general principles, nearly as they are now made, but it was not until the year 1787 that I completed my invention, when I took out my last weaving patent in August in that year."

This also included the art of weaving checks, which the most skilful mechanics, even after they had seen his first machines in operation, deemed to be impossible by any except manual means.

The weaving factory, which was erected at Doncaster by some of Cartwright's friends, with his license, was unsuccessful; and another establishment, containing five hundred looms, built at Manchester, was destroyed by an exasperated mob, in 1790. The invention, however, has surmounted all opposition, and at the time of the Doctor's death it was stated, that steam-looms had increased so rapidly, that they were then performing the labour of two hundred thousand men!!

Cartwright's next invention was a method to *comb wool with machinery*, which excited, if possible, a still greater ferment among the working classes than even the power looms. The whole body of woolcombers petitioned Parliament to suppress the obnoxious machines, but without effect; and the combing engines began to be used by some ma-

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machines acting by a single impulse. It should not, however, be forgotten, that these engines were first experiments, and that Watt had spent thirty years of his life in perfecting that machine with which

nufacturers, who at the same time attempted to evade Cartwright's claim as their inventor. After a trial, which occupied the Court for twenty-six hours, he established his right, and gained a verdict for damages for one thousand pounds against the pirates.

Notwithstanding the benefit these inventions were to the cotton and woollen manufactures, their author had reaped no emolument from them, but, on the contrary, had drawn on his family and himself a heavy loss; for although his claim latterly was unquestioned, and Parliament, to encourage his meritorious exertions, had liberally extended the term of his patent right, he had all along to contend with the opposition of the working classes, and the fears of the manufacturers in general, who were not only deterred by the threats of the incendiaries, but the actual destruction by fire of the establishment at Manchester, soon after a few of the machines had been put into action. Besides, his clerical character prevented him from introducing his engines, or disposing of their produce as a manufacturer. In consideration of these circumstances, and on the petition of a number of commercial men at Manchester, and other places, Parliament, in 1810, made the Doctor a grant of ten thousand pounds as a reward for the ingenuity of his inventions, which had already become of national importance. This sum, although munificent as a present, was barely adequate even to repay the sums the Doctor had expended in experiments. His family has reaped no pecuniary benefit from his ingenious and successful labours, persevered in during a long and active life; yet the results of these exertions are now ranked among the valuable elements of our national manufacturing superiority; and are acknowledged to have realized large fortunes to many individuals since they became public property.

Doctor Cartwright was the author of numerous other inventions in the arts and agriculture, for several of which he received premiums from the Board of Agriculture and the Society of Arts. Among other things, he contrived a carriage, with which he often astonished the natives of London, by working and steering it through the streets without horses; and he expressed himself with great confidence, that this child of his old age would, ere long, be adopted into ge-

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they were put into competition. The general arrangement of the parts is excellent, the details are ingenious, and altogether the machine was worthy of much greater perseverance being given to its improvement, than appears to have been bestowed by its excellent author.

The contrivance, however, for which Cartwright is better remembered, as an improver of steam mechanism, is a very unobtrusive, yet most important, alteration in the construction of the piston. In the modes hitherto, and even at this time practised, a layer of hemp, or of some other elastic substance, well soaked in oil or tallow, was wrapped round the external edge of the piston, and by different means was pressed outwards so as to be steam-tight, and yet allow the piston to be moved easily upwards and downwards.

As will be readily understood, this packing was far from being durable, and of course the piston could not long continuet o be effective. Besides, all the steam which escaped past the sides of the piston produced no effect and was a waste of fuel. The mode of packing to make the piston steam-tight, also became another prolific source of loss of power; for it was so tightly rammed as in

neral use; and that, in a few years, similar carriages would travel turnpike roads without horses.

Till within a few days of his death he retained all the faculties of his mind perfectly unimpaired, and was occupied almost to his last moments on the details of a novel and extraordinary invention, of a new power, for moving machines. Gunpowder is said to have been the initial agent in his discovery.

He died in the winter of 1823. He had been twice married, and left a son and three daughters by his first wife, Alice, a daughter of —— Whitaker, Esq., of Doncaster. His second wife was a daughter of Dr. Kearney, a dignitary of the Irish church.

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many cases to absorb a very great proportion of the power of the engine to move the piston—this was an expensive as well as vexatious defect, for the time required to open the cylinder, and re-adjust the packing, was a serious hinderance to the general business of the manufactory, as well as a loss to its proprietor.

The device Cartwright proposed to obviate all these objections was an excellent one. Instead of hemp, he used segments of brass plate-rings laid above each other, so as to break the continuity of the vertical joints; and these segments were kept in their position by means of small springs, placed at the joining of each two pieces. The first figure in the engraving marked PISTONS, is given from Cartwright's own illustration. It has since his time received some modifications, which form the other figures on the same engraving.

Sadler's skill in mechanical combination is seen to much greater advantage in his reciprocating engine, than in his steam-wheel. It had the great honour, also, of being the first engine introduced into a national naval establishment—a circumstance not a little extraordinary, for, although, compared with some other attempts, its claims are considerable, even in its most perfect form, it is greatly inferior to the condensing engine. Yet, notwithstanding the merit of the Soho engine, it was rejected in the competition; but some years afterwards, when Sadler's apparatus (of about ten horse power) was taken down, in consequence of a more powerful apparatus being found necessary, one on Watt's model was substituted. In the figure, the parts of Sadler's machine are shown, in the position they would assume at the commencement of a stroke; the steam valve *e*, is open, and a jet rises in the condenser, which is open at top

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to the atmosphere—this jet condensing the vapour forms a vacuum under the steam piston, which is pressed downwards by the elasticity of the vapour. When the piston arrives near to the bottom of the cylinder, the steam and injection valves are closed, and the equilibrium valve, *x*, in the piston is opened, and this forms an equilibrium between the top and bottom of the piston *b*, and the momentum of the fly then raises the pistons to their first position, and at this instant the steam and injection valves *e*, *h*, are opened, and the piston valve *x* shut, and the same action again commences.

But when the fall of the piston *b*, had opened the equilibrium valve, *x*, the elasticity of the steam which issued through it, lifted up the condenser valve, and expelled the greater portion of the air and injection water, which the condenser contained, through the drain pipe *m*, and the valve *f*, in the air-pump piston. The diameter of the condenser was equal to that of the working cylinder, but its stroke was only half of the length of that of the steam-piston. The air-pump being open to the atmosphere, the great weight on it, which is required to be raised by the momentum of the fly-wheel, would appear to be a loss of power, without the least advantage; but this is returned to the machine in the effective stroke. The reciprocating motion is converted into a rotary one, by the mechanism shown in the sketch; the great lever was dispensed with.

In engines on every form, it was of great consequence to preserve a uniformity in the rate of the production of steam in the boiler; for the elegant contrivance which was so happily adapted by Watt, for regulating the quantity of steam flowing into the cylinder, was partially ineffective, as

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long as the elasticity of the vapour itself varied every instant. Only two ways were known of obviating this defect—one was to regulate the supply of fuel, and the other to regulate the admission of the air which assisted in its combustion; but both the one and the other had to be done by the hand of the fireman, and on his attention and regularity depended the uniformity of motion in the engine; and it could not be a matter of surprise, that even with the most careful management, the steam accumulated sometimes to a dangerous elasticity in the boiler. Mr. Matthew Murray, whose manufactory at Leeds was rapidly extending to become a competitor with Soho, in its hitherto exclusive manufacture, placed a cylinder and piston on the boiler, whose toothed-rod worked into a wheel, the axis of which was prolonged, and formed the axis of a valve which was placed within the flue of the boiler chimney; when the accumulation of steam in the boiler increased its elasticity, it lifted up the piston in the pipe, and this acted to turn the spindle on which the valve was fixed; this diminished the smoke-way, and continued to do so until the combustion of the fuel was so much lessened, and the steam in the boiler reduced to the ordinary quantity; when the elasticity was lessened, the piston had a tendency to descend, which was increased by a weight which had been wound up by the ascent, and the valve or self-regulating damper was returned into its first position. Murray also made some engines with the piston working in a *horizontal position;* and at the same time described a combination for converting the reciprocating motion of the beam into a continuous one. But Watt's contrivance becoming soon

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after the property of the public, its use superseded this and many other rotary movements.

Murdoch's steam-wheel, or rather wheels, is shown in one of the figures of the plate marked ROTARY MOTIONS: the vapour enters at *a*, and a vacuum is maintained by means of a condenser *b*; a rotary motion is produced by means of the leaves of the wheels working into each other. Murdoch's elegant contrivance for connecting the upper and lower valves by the same spindle, and forming that hollow to serve as an eduction pipe to either end of the cylinder, freed the engine from a pair of valves. And his invention for opening and shutting these valves, by a circular motion produced from the revolution of the axis of the crank or fly-wheel, is one of those which is now found in the greater number of the best constructed machines, in place of the clumsy plug frame.

Bishop's engine was something like an overshot water wheel; the lower buckets in their revolution, were filled on one side with steam, and the upper buckets on the other side were filled with water; the wheel also moved in water, and the difference in the gravity of these two portions of the circumference gave a circular motion.

During the continuance of Watt's monopoly, many schemes had been tried to adapt the condenser to the atmospheric engine. Yet, no hint had been thrown out, that this addition would save heat and economise power, if applied to Savery's engine, until Mr. John Nuncarrow, a native of Devonshire, who had settled at Philadelphia, gave a description of an apparatus for this purpose *.

* *Trans. American Philosophical Society*, vol. i. p. 209.

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In the figure marked NUNCARROW, the steam is issuing from the boiler *a*, through the pipe *b*, and valve *c*, into the receiver *d*, and is forcing the water which it contains through the valve *m*, into the reservoir *p*, whence it falls on float-boards on the wheel *s*, and makes it revolve. When all the water above the level of the valve *m*, has been raised into the reservoir, the steam valve *c* is closed, and the condenser valve *e* is opened, at the same time that a jet of water rises into the condenser pipe *x*, a vacuum is made in *d*, the pressure of the atmosphere then raises water through the valves *i i*, which open upwards only, and the valve *m* is shut by the pressure of the water above it; the receiver *d* is thus again filled with water; the valve *o* is then shut, and *c* opened, and the water is pressed through the valve *m* as before; the pressure of the water which opens it, shuts the two lower valves *i i*, as in the engraving.

Whatever opinion may be formed concerning the practical merit of Hornblower's steam-wheel, it must always be considered as a machine, original in its conception, displaying in its development great skill in mechanical combination, and as a whole, placing its author far above the rank he has been classed in from his previous labours on the reciprocating engine.

It had not escaped Hornblower's observation, that the passage of a piston over a slider or valve, or any opening or groove, was a circumstance alone sufficient to be fatal to the durability of every mechanism in which it was practised. Hempen packing was destroyed by being torn out of its place, and the edges or surface of the grooves or sliders, if metallic packing were used, would be acted on, by the passage of the piston over them, so as to destroy that sharpness of finish,

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which it is essential to preserve in all the rubbed or rubbing parts, in order to their being steam tight, or to their smooth and, of course, durable action. In Bramah's designs this defect was very apparent, and in the schemes of his predecessors, it is greatly magnified, with the exception of Sadler's, which in effect was a mere toy.

Hornblower's mechanism was well calculated to avoid these objections, for the inside of his cylinder was preserved free from all grooves or perforations, either for the admission of steam, or for the beds of valves or sliders, by operating with two moveable diaphragms or pistons, each of which alternately acted as the steam piston, and as the abutment valve. The same letter, in all the figures of the engraving marked HORNBLOWER, B, refers to the same part; *a*, is one of the diaphragms or pistons; *b*, the other; *d*, *e*, are their axles, which are formed hollow; the axle *a*, communicates by the opening *f*, with the box *g*, which is open to a condenser by the pipe *h*; and the axle *b*, communicates by the opening *i*, with the box *k*, which is open to the boiler by the pipe *l*; the motion of both pistons is independent of each other, each moving round the solid axle *m*, in the same manner as a door-hinge; this solid axle transmits the motion of the piston *d*, to the machinery, by a contrivance not shown in the engraving. To each axle jointed levers, shown in figure 2, are attached, and these are arranged so, that when the diaphragms move forward, they slide without offering any resistance, in a circular groove; but upon the least tendency in the pistons to a retrograde movement, the levers *o*, *o*, act to press the part *p*, *p*, forcibly against the circumference of the groove, and to retain the piston firmly in that position. This system of levers will

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therefore, be sliding in their peculiar groove, while the lower series attached to the other piston, are pressing the levers *p*, *p*, forcibly against the circumference of the groove in which they slide, preventing the diaphragm to which they are attached from moving. If steam flows into the piston chamber, through the valve *r*, into the space between the pistons *a* and *b*, the piston *b* will move towards *s*, and the series of levers attached to it will slide in their grooves; but as the elasticity of the steam presses the other piston *b*, in an opposite direction, this tendency to retrograde acts to make the levers attached to it, press against the circumference of their groove, and to keep it firmly fixed in its position. When the moving piston has approached very near to the fixed one, the tail of the closed steam valve coming into contact with a projection on the other piston, that valve is opened, and at the same time, the valve at the other side of the piston is shut. The steam now acts on the opposite side of the piston, which gives it a tendency to retrograde, and this brings the jointed levers or clamps into operation, to fix it in its position; it is now the abutment valve; but at the instant when the steam valves were reversed, the valves in the other piston were reversed also, that which had opened the entrance to the condenser from the cylinder, was shut, and the corresponding valve on the other side the piston, was opened; this piston is, therefore, now the moving one; for being impelled in the assigned direction, its levers are arranged to slide in their groove, while those attached to the other piston, as has been described, act to fix it in its position. When, in its revolution, the piston *b*, approaches very near to

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this fixed diaphragm, the valves in both pistons are again reversed, and so on alternately.

The small wheel *u*, acts in the screw to shift the ring *w*, upwards or downwards, on the axle, and to regulate the size of the orifice, through which steam flows from the boiler.

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CHAPTER TWENTY-SECOND.

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"ALL MEN NATURALLY THINK THEMSELVES EQUALLY WISE; AND, THEREFORE, AS ANY SHIP THAT SAILS FASTER THAN ANOTHER, IS SAID, IN SEA PHRASE, TO WRONG IT, SO MEN ARE APT TO THINK THEMSELVES WRONGED BY THOSE WHO, WITH BETTER TALENTS THAN THEY, OR GREATER SKILL IN THEIR USE, GET BEYOND THEM."—*Hartlib.*

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If Watt throughout has been remarkable for his good fortune, his merits seem equal to the highest success. But that very prosperity which should have been a source of pride and satisfaction to all ingenious men, seemed only calculated to excite their mercenary hostility. Many of the schemes which have been put forth as improvements, aspire to no higher character than attempts to make use of Watt's ideas, but to evade his claims; and if, during the last ten years, in his engines improvement appeared to have been nearly stationary, and the invention of their author to be apparently in a state of repose, while that of his enemies was in incessant activity, yet he must be considered as having been reclining on any thing but a bed of roses. In fact, he had long been harassed by a series of insidious and persevering attacks, both on his reputation as an inventor, and on his rights as a patentee; and in

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repelling these, years of his time had been thrown away.

The condenser was the part coveted, and its shape, action, position, had all been altered, or disguised in the progress of evasion.

One course alone was open to Watt and Bolton, and that course they pursued silently but vigorously. And probably there is no other instance of a patent being the subject of so many appeals to the law, coming out unimpaired of the struggle.

When it was contested on the plea of being wanting in originality and merit—men of the highest personal and professional character, united in the most unqualified commendation of the singular value of the condensing engine, which they described to be as original in its conception, as it was transcendant in the ingenuity of the means by which the idea was carried into effect; and the witnesses, jury, and judges, felt and acknowledged its importance, as an element of national prosperity. When overwhelmed by the concurrent testimony of a host of eminent men, Watt's opponents were driven off the ground they themselves had chosen, a fresh attack was organised and commenced on the patent, on the plea of the written description which Watt had given in 1769, shortly after he had made the discovery of the condenser being imperfect. This, as has been already stated, was drawn up, after the erection of a rude model, at Kinneil, which was all that his means or his patron enabled him to construct—and with no more experience than he had acquired from this coarse experiment.

But twenty years afterwards, or rather after a series of experiments in which he had been engaged for twenty years, to develope his ideas, the

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splendid result of his genius and perseverance—the perfect machine—was raised up in judgment against him, to prove that between the years 1790 and 1800, the engines which were sent from Soho, were more perfect than could be fabricated from the description he gave of the one he erected in 1769!! Generous rivals! nay, several of his adversaries confessed, that the machine was yet the subject of expensive and elaborate experiments; for they had, it seems, seen recent engines with very varied proportions,—and they went so far as to acknowledge that some of the parts which Watt had introduced, did not appear to them to be essential to the precise, or effective action of the mechanism; yet these parts were pointed out as having no existence in the document of 1769—and, because they had not, Watt, in their opinion, was not entitled to the reward of his admirable invention. Consistent reasoners! But when men of genius come into hostile collision, we seek to find a spark of that spirit, which raises them above the vulgar herd, tempering, and infusing a generous feeling into their rivalry—and it is on this account, that among all those who gave vent to their splenetic disappointment, in their opposition to Watt, the name most conspicuous, and one most to be regretted as being found there, is that of the excellent Bramah; and yet from his known regard to truth, and his personal integrity, his opposition, notwithstanding its asperity, must be considered far removed from the imputation of being tainted by corrupt, or even interested motives.

His printed letter to the Judge, who presided at a trial, in which Bramah appeared as a witness, on the side opposed to Watt, evinces great acuteness, a perfect knowledge of the subject, a caustic wit,

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and a sturdiness of opinion, which made him a formidable opponent. But resting on the necessity of a rigid adherence to the very letter of the law, he lost sight of its kind and benevolent intention as well as of the broadest principles of justice.

His production throughout is a series of admissions of the value of Watt's contrivances; and he points out inventions that had escaped the notice of others, with all the fine feeling of what is beautiful in an art, in which he himself was a master; and while displaying them, he extols their ingenuity. But he ceases not by inference to ask, if the inventor has described these in a proper manner; and he comes always to the conclusion, that because he has not, therefore he is not entitled to any reward for his superlative invention. It did not once occur to this gifted individual, to refer to the form of the first machine, from which only, Watt could write a description.

Some of the judges who had paused at points raised by the sophistry of counsel in a former trial, were unanimous on this. "Every new invention," says the Chief Justice, "is of importance to the wealth and convenience of the public, and when they are enjoying the fruits of a useful discovery, it would be hard on the inventor to deprive him of his reward—the Jury have found that the inventor has sufficiently described the nature of his invention, and I think he is, in point of law, as well as justice, entitled to the benefit which was intended to be conferred on him, by the patent and Act of Parliament." *

* "Laws for securing MENTAL PROPERTY meet with but little of the respect paid to those which guarantee the enjoyment of more substantial and visible acquisitions. It is not difficult for the artful and avaricious, to make it be believed

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But in point of fact, no more unanswerable arguments could be adduced in favour of Watt's claims, than this identical letter, which was meant to destroy them. Its author might be pointed to as the greatest and most gifted of his opponents—as a man of experience, almost equal to Watt himself, in mechanical labours—and possessing an imagination, of a cast as creative as his—himself the author of inventions described in more than twenty patents—some of them equal, in their value to society, even with the steam-engine. And above all, as connected with this matter, Bramah was well learned, in what may be called the erudition of his art—a knowledge of what had been done by others. Yet even he, in opposing Watt, stood on no higher ground, could justify his *volunteer* opposition, on no other principle, than the technical imperfections of a document, drawn up by a man, at that time possessing little skill in the matter he was describing, and still less in the art of putting what he meant to say, upon paper.

It is not, however, to be regretted, for the fame of Watt, that he had so acute and so powerful an adversary; for the weakness of the ground that could alone be occupied against him is a test of the strength of his own position.

But it had been more gratifying to have seen Bramah, with more kind feeling in his rivalry, for

that they are unmerited and odious monopolies, or to persuade that the adversary of exclusive rights is their friend. Very many think there is no injustice in attacking or evading patents; on the contrary, if the letter of the law can be evaded by any subterfuge, they think it would be meritorious to do it. They consider a patentee's privileges as fair objects of plunder, and have no hesitation to endeavour to rob him of them under the most frivolous pretences."—*Colden, p.* 142.

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it does not require the gift of prophecy to foretell, that the names of Watt and Bramah, who lived in the same age, and adorned the same art by their exquisite inventions, will be classed together, as entitled to the grateful remembrance of posterity, for the benefits their labours have conferred on their country.

It is probable that the harassing nature of the opposition he had for years encountered, had some influence in determining Watt's resolution to withdraw altogether from business, on the expiration of his patent. Resigning to his son, and the son of his colleague, the future management of that establishment which his genius had matured, and to which it had given a celebrity, as wide as the boundaries of civilization, he retired to the enjoyment of the fortune, which he had accumulated from the meritorious and well directed exertions of a life distinguished for its activity and usefulness.

The period, in our narrative, at which we have now arrived, had long been anticipated with great anxiety, by all those engaged in the manufacture of steam-engines, and by the still more numerous class interested in their use and extension. The term of twenty-five years, during which Parliament had granted to Watt the sole benefit arising from the condensing engines, expired in 1800, when the fabrication of his beautiful machines was thrown open to the public.

Numerous schemes in embryo, it was supposed, would make their appearance when their authors could bring them into being, with all the advan tages of an unrestrained participation in Watt's contrivances; not a few failures also were to be retrieved, when the parts which were held forth as being essential to their perfect action might be

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added:—there were a crowd of mechanics, who, without so much ambition as to aspire to the character of inventors, yet saw a great field open for improvement, in the opportunities for putting their own ideas, of the best forms and proportions, into practice. All announced the commencement of a new era, in which exertions, hitherto borne down by the Soho monopoly, were, at their emancipation, to expand and give the finishing touches to the perfection of the mechanism in those parts, allowed on all hands to be capable of great improvement.

A point on which practical men were, however, well agreed, was the effect of the unrestricted use of Watt's engine leading to its more general introduction as a first mover, into manufactories; for although the "*third part of the savings of fuel*," which was reserved by Bolton and Watt, ought, in reason and fairness, to have been considered as an index only of the benefit conferred by Watt's invention, it was more often felt as an oppressive and heavy tax, particularly by those whose knowledge of steam-engines was acquired from their experience with Watt's alone, and who only knew of Newcomen's machine from its connexion with the payment they were called upon to transmit to Soho; and this feeling made many persevere in employing Newcomen's apparatus, or the labour of animals, until the invention became common property. In Cornwall, however, where, from the dearness of fuel, its advantages were seen in the true light, its use had become nearly general. But in other districts, where coals were cheaper, it had made but comparatively slow progress; and, strange as it must appear to us, where a continuous rotary motion was indispensable, New-

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comen's engine was still resorted to; and even Savery's machine was used in many places to pump water to turn a water-wheel.

In London, at the expiration of the patent, not more than a power equal to the energy of six hundred and fifty horses was exerted by Watt's engines; in Manchester about four hundred and fifty horse-powers; and at Leeds about three hundred horse-powers, and at the same time (in 1800) not more than four steam-engines of any importance were at work in the whole continent of America. One of these supplied New York with water, and the other two belonged to the corporation of Philadelphia.

These facts will give some notion of the extent to which steam was applied as a first moving-power in other places; and from its limited amount will offer a remarkable illustration of the effect of an exclusive privilege in fettering production, even although the monopoly was one held by the fairest claim, and managed on the most liberal system; and showing that a diffusion of interest is essential to the spread of improvement. In this particular instance, a circumstance, which has already been adverted to*, as being a fortunate one for Watt's reputation as an inventor, his becoming the sole manufacturer of his machines, had great influence in exciting the commercial hostility against its introduction in a class which might have been conciliated by permitting it to participate in the manufacture of the engines. The fact is extraordinary, that in five years after the patent had expired, the number of Watt's engines in London had doubled, and in that time Watt and Bolton had sold a greater number of ma-

* Page 271.

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chines than they had done in an equal time, when they possessed the sole right to manufacture all the engines used in England.

The first invention which is recorded in the new era is Crowther's. He placed the fly-wheel above the cylinder, in the same manner as Cartwright did, and connected it to the steam piston rod, without the intervention of a great lever. The combination, although not altogether original, was clever, but yet it offered no advantage to machines constructed on the common model. In Cartwright's second project, he only professed to combine the parts of the condensing engine, to produce a more portable, light, and compact machine. Hase, instead of conducting the steam which had moved the piston at once from the cylinder into the condenser, made it pass through a number of small pipes, all of which communicated with the condenser; these being inclosed in a vessel surrounded with cold water, some of the heat was extricated from the vapour, and the water which by this means became heated, was pumped into the boiler, at a temperature higher than could be done by the common mode of using that which had been heated by the air-pump, or drawn from the condenser.

Murray's ingenuity was again exhibited in his construction of a pump to discharge the air without the use of valves, as in the common method, and also to discharge the air and water separately.

The pump is shown as attached to the condenser; *b*, the piston; *c*, a pipe connecting the top and bottom of the air-pump, having a valve *d* opening downwards into the cylinder; another valve *e*, on the top of the pump, opens upward; *f*, pipe connecting the air and water pump, of which *h* is the bucket; when the piston *b* is at

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the top of the cylinder, the air which remains after condensation, occupies the area of the air-pump and the condenser. When the piston *b* descends, the air which was beneath it flows through the pipe *c*, into the space above it, and when it ascends, the air being prevented from returning by the valve *d*, it is forced out through the valve *e*; the water falling into the pipe *g*, is lifted by the bucket *h*.

In another part of the same engine, he introduced a capital improvement in the arrangement and construction of his valves, the axis of one was inserted through the spindle of the other; this, in appearance, was similar to Murdoch's, but the form adopted by Murray was excellent, and is now very generally used in steam-engines.

Murdoch, to whom, on the retirement of Mr. Watt, the management of the manufacture of steam-engines at Soho was confided, had, before the date of Murray's patent, put in practice a similar mode of forming the spindles of the steam valves like tubes, to allow the spindles of the other valves to slide through them, but it does not appear that he had made public any description of his improvement; although it must be admitted, the transition from the spindle being made hollow to serve as an eduction-pipe, to a solid spindle, was so obvious, as to follow almost as a matter of course; and this coincidence between the inventions gave rise to a lawsuit, in which the opinion of the court was given against the patentee; and the other schemes which were described in the same document, and which all allowed to be original and remained unquestioned, were at the same time thrown open to the public, or rather destroyed to the inventor; in accordance with that most extraordinary principle of the

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equitable law, that a patent must be good for every thing contained in it, or good for nothing.

The three engravings marked MURRAY exhibit an elevation, and a vertical and horizontal sections of a species of engine, usually constructed by this engineer; and although this identical form should have been described a few years later, it is placed here to give an idea of Murray's style of mechanism in connexion with a notice of his improvements upon it generally.

Murray, and his associates, Fenton and Wood, at Leeds, were among the first who studied to improve the general symmetry of appearance of the steam-engine, by arranging its parts with a view to elegance, as an object of taste, as well as to its portability, compactness, and durability as a mechanical agent; in the attempt they were eminently successful; for on an inspection—

> "Of this frame, the bearings and the ties,
> The strong connections, nice dependencies,
> Gradations just" . . . .

it will challenge our unqualified admiration, as a specimen of the most picturesque elegance in forms and grouping; and this machine, capable of exerting a power equal to that of forty or fifty horses, (or that of between 200 and 300 men,) from its tasteful ornamental appearance, may vie, as a decoration of a drawing-room cabinet, with the most costly piece of embellished clockwork mechanism.

It were superfluous to describe the action of this fine machine,—this will be easily understood by a mere enumeration of its parts, and an inspection of the figures.

a, the cast iron frame, within which the engine is placed, and to which its parts are firmly united; *b*, the steam-cylinder; *c*, steam-piston; *d*, piston

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rod attached to the parallel motion; *e*, beam; *f*, connecting rod; *g*, crank with globe pin; *i*, fly wheel; *k*, condensing cistern; *l*, air-pump; *m*, hot well; *n*, condenser; *o*, eduction-pipe; *p*, cold water pump; *q*, hot water pump; *r*, governor; *s*, steam pipe; *t*, valve case. The manner of admitting the steam above and below the piston, is different from any that have been described—it is by a *sliding valve;* this contrivance was introduced by Murdoch, into some of the small engines made at Soho, and called by him the D valve—it was also much used by Murray and Fenton, in the engines they fabricated at Leeds, and with some variation. We know not, however, whether to ascribe its invention to Watt, or Murdoch, or Murray. It is very simple, and on a small scale; it can be made very effective, and is easily kept in order.

From Bramah the four-way cock of Papin received a great improvement, by the passage for the steam being made at the larger end of the revolving cone, and passing off at the smaller end; by the pressure of the vapour being upon one extremity of the cone, while the opposite one was relieved from it, the valve was always kept tight in its socket. And instead of the cock being turned into its position, and returned alternately, Bramah by an alteration in the tappets, made it act so as to revolve continually.

In the erection of machinery, Mr. John Roberton, of Glasgow, had acquired much local celebrity; and his practice on the large scale, particularly at the formation and extension of the great establishment on the Isle of Bute, opened to him some original views on hydraulic action, of which he availed himself with much skill in his subsequent practice. Roberton made a very inge-

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nious alteration on Watt's mode of producing the combustion of the smoke, and which was applied in numerous instances with a good effect; some improvements, which he introduced in machinery for the manufacture of cotton, have since his time been revived, and the merit appropriated by others.

In the hands of even the most expert fabricators of steam-engines, a considerable portion of steam found its way past the piston, into the condenser. To avoid this, he employed two cylinders, placed over each other; the under one, *b*, of somewhat larger diameter than the upper one, *a*, of which it formed a continuation. When the valves were in the position shown in the engraving, the steam which escaped past the upper piston *c*, filled the annular space *d e*, and assisted to depress the lower piston.

Roberton enumerated several of the advantages of this mechanism, in the description of its construction which he gave to the public, and erected some machines on this peculiar plan, which gave satisfaction to their proprietors, besides one in his own manufactory; but the perfection which shortly afterwards was given to the mechanism of the piston and cylinder, removing many of the objections which his clever mechanism was introduced to avoid, it is now probably obsolete in practice.

The narrative which Mr. Miller gave of his father's attempt to construct a steam-boat, and from which we have made some copious extracts, agrees with an account of the same experiments which was given in a sketch of navigation by steam, inserted in the Supplement to the *Encyclopedia Britannica*.

Symington, who appears to have been more

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sanguine than his first patron, of the practicability of navigating vessels by steam, nearly twelve years after his experiments at Dalswinton Loch, found an opportunity to bring his scheme under the notice of a nobleman, who was zealous to encourage projects which had for their object the improvement of inland navigation. Symington, who imagined that a boat moved by wheels could be introduced with great economy, as a substitute for horses, in towing boats on canals, succeeded in inducing Lord Dundas, of Kerse, to assist him to make an experiment, on a great scale, on the Forth and Clyde Canal, with machinery, resembling in its principle that of the Dalswinton model, but modified to suit the purpose which he had more immediately in contemplation.

The result of this application, and the character of his patron, may here be noticed with reference to Symington on another account, besides its connexion with a history of his experiment. From an expression in Miller's narrative, that his father was discouraged from proceeding farther from a feeling of disgust at having been involved in unnecessary expenses, an inference might be drawn unfavourable to the memory of an ingenious and worthy man.

But Miller's complaint is, in truth, a very common one; and the estimates even of the most experienced mechanics will probably continue to differ widely from the final outlay, even although those artists have been experimenting on their own means. But patrons can hardly be blamed for their keen expression of disappointment at the cost of labours purely executive, being so little understood by practical men, though operators, on the other hand, will cast the reproaches from

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themselves as being groundless and unmerited, from viewing their object through a medium somewhat tinged with enthusiasm. Nothing, however, can be more clear, than that Lord Dundas, himself a man of experience, and who had the best means of being correctly informed on every point connected with the operation at Dalswinton, was satisfied with Symington's conduct and judgment on that occasion; for those experiments which were made at his Lordship's cost, and on which a large sum of money was expended, were conducted solely under Symington's superintendence; and he, also, subsequently, received the commendations of his noble patron for his exertions.

"Mr. Miller," says Symington, in his narrative, "being very much engaged in improving his estate in Dumfriesshire, and I also employed in constructing large machinery, for the lead mines at Wanlockhead, the idea of carrying the experiments at that time any further, was entirely given up, till meeting with the late Thomas Lord Dundas of Kerse, who wished that I would construct a steam-boat for dragging vessels on the Forth and Clyde Canal, instead of horses. Agreeably to his Lordship's request, a series of experiments, which cost nearly three thousand pounds, were set on foot in 1801, and ending in 1802, upon a larger scale (than those on Dalswinton Loch) and more improved plan, having a steam cylinder twenty-two inches diameter, and four feet stroke, which proved itself very much adapted for the intended purposes. Having previously made various experiments in March 1802, on the Forth and Clyde Canal, Lord Dundas and several other gentlemen being on board, the steam-packet took in tow two loaded vessels, each of seventy tons burden, and moved with great ease through the canal,

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a distance of nineteen and a half miles in six hours, although the whole time it blew a strong breeze right a-head of us, so much so, that no other vessels could move to windward in the canal that day but those we had in tow, which put beyond the possibility of a doubt, the utility of the scheme in canals and rivers, and ultimately in open seas. Though in this state of forwardness, it was opposed by some narrow-minded proprietors of the canal, under a very mistaken idea that the undulation of the water, occasioned by the motion of the wheel, would wash and injure its banks. In consequence, it was with great reluctance laid up in a creek of the canal, exposed for years to public view, where Henry Bell from Glasgow, who also frequently inspected the steam boat at Carron, in 1789, did also particularly examine this."

During the time that he was engaged in this experiment, Symington received a visit from a Mr. Fulton, "who," says he, "politely made himself known, and candidly told me, he was lately from North America, and intended to return thither in a few months; but having heard of our steam-boat operations, he could not think of leaving the country without first waiting upon me, in expectation of seeing the boat, and procuring such information regarding it as I might be pleased to communicate. He at the same time mentioned, however advantageous such an invention might be to Great Britain, it would certainly be more so to North America, on account of the many extensive navigable rivers in that country. And as timber of the first quality for building the vessels, and also for fuel to the engines, could be purchased there at a small expense, he was decidedly of opinion, it could hardly fail, in a few years, to be-

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come very beneficial to trade in that part of the world; and that his carrying the plan to North America, could not turn out otherwise than to my advantage; as if I were inclined to do it, both the making and superintending of such vessels would naturally fall upon me, provided my engagements with steam-boats at home did not occupy so much of my time, as to prevent me from paying any attention to those which might afterwards be constructed abroad. In compliance with his earnest request, I caused the engine fire to be lighted up, and in a short time thereafter put the steam-boat in motion, and carrying him four miles on the canal, returned to the place of starting, to the great astonishment of Fulton and several gentlemen, who at our request came on board. During the above trip, Fulton asked me, 'if I had any objections to his taking notes respecting the steam-boat?' to which question, I said 'none;' and after putting several pointed questions respecting the general construction and effect of the machine, which I answered in a most explicit manner, he jotted down, particularly, every thing then described, with his own remarks upon the boat;" "but he seems," says Symington, "to have been altogether forgetful of this, as, notwithstanding his fair promises, I never heard anything more of him till reading in a newspaper an account of his death."

From these facts, the author of the sketch thinks it is very evident Symington was the first person who had the merit of *successfully* applying the power of the steam-engine to the propulsion of vessels, and that there can be but one opinion, that in its influence on the fate of a most ingenious man, there existed not enterprise enough in Scotland, to encourage this excellent artisan to repeat

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his interesting and important experiments on the river Clyde.

About the time Symington had abandoned his experiments, M. Des Blanc, a watchmaker at Trevoux, had built a steam-boat, and made some experiments with it on the river Soane. The first attempts were so successful as to bring forth the Marquis de Jouffroi, with his prior claim; the final result, however, was as hapless as the Marquis's.

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CHAPTER TWENTY-ONE.

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" LIKE ONE THAT DRAWS THE MODEL OF A HOUSE
BEYOND HIS POWER TO BUILD IT; WHO HALF THROUGH
GIVES O'ER, AND LEAVES HIS PART-CREATED COST
A NAKED SUBJECT TO THE WEEPING CLOUDS,
AND WASTE FOR CHURLISH WINTER'S TYRANNY."

Shakspeare.

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Of the numerous projects afloat, one apparently very seductive to mechanical men, as well as most important to the public, was a mechanism to move a carriage along roads, by means of a steam-engine, in place of the power of horses.

If Cugnot's experiment had ever been known in England, no traces of it can now be discovered; and the carriage Watt described can be considered but as a crude first thought; for it is difficult to imagine any modification of the condensing engine, which could ever make it become the means of moving a steam-carriage. In itself it was complex, bulky, and ponderous; the water for condensation required to be continually renewed, and this alone would almost operate as an exclusive bar against its adoption. In fact, instead of so unwieldy a mechanism moving a long train of heavy carriages from its surplus power, it might have required some extraneous power to move it along.

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Leupold's scheme was not matured, and although Watt * had mentioned it when mentioning his carriage, it is certain he never carried it into practice: indeed, his idea of condensing the steam by air, is sufficient to show that his description was a mere thought; and his account of moving pistons by steam against the air, forty-five years after it had been promulgated by Leupold, was, however, in terms so vague, as to warrant the belief that he had never seen the German's account of it. Besides, to the period of his death he retained rooted prejudices against the use of steam of a high temperature, on account of its danger, as well as because he considered its use gave no economical advantage over vapour of a much lower elastic power.

If the invention of a steam-waggon were not, therefore, a hopeless project, it was one sufficiently improbable to deter plodding prudent men from engaging in it, with the mechanical means then in their power.

It will be obvious, that from the nature of the objections to the use of the condensing engine, as a mover of carriages, either that steam must be given up, or some other mode of applying its impulse must be resorted to, than had been yet practised; for, in fact, the intermediate mechanism by which the carriage was to be propelled, was in this case a matter of secondary importance only.

* "I soon relinquished the idea of constructing an engine upon this principle, from being sensible it would be liable to some of the objections against Savery's engine, viz. the danger of bursting the boiler, and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston.

"I however described this engine in the fourth article of my patent, in 1769, and again in the specification of another patent, in the year 1784, together with a mode of applying it to wheel-carriages."—*Watt's Narrative.*

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In a bold deviation from the beaten track, it was the good fortune of Mr. Richard Trevithick and Mr. Andrew Vivian, two engineers residing at Cambourne, in Cornwall, to find the path which conducted them to their object; rejecting the absurd prejudices which had made high-pressure steam be excluded from practice, they saw in the formidable qualities which had excited the fears of Watt and others, those very properties which fitted it to become the actuating principle in their portable apparatus. Above all the other considerations which swayed them in their preference of steam of a high temperature, was the power it gave of dispensing with the use of the condenser altogether, a part which, from its cumbrousness, and the difficulty of supplying it with water, in fact, made Newcomen's imperfect apparatus better adapted to locomotive purposes than even the Soho engine. It is somewhat singular, too, that although during the thirty years that Watt's monopoly existed, the whole ingenuity of practical men appeared to be directed to form an apparatus, in which the use of the condenser was essential to its proper action, yet no sooner had this invention become public property—the same year —than a scheme was matured, and carried into effect, which, of all the applications of this power, as a whole, touches not in any point—does not even approximate to any of Watt's ideas as exhibited in his condensing engine.

The boiler *a* in the engraving (marked TREVITHICK and VIVIAN) is made of a circular form, and is inclosed in a case *b*, luted with fire-clay; *c*, the piston cylinder, the greatest part of which is inclosed within the boiler; *d*, a cock for permitting steam to pass from the boiler into the cy-

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linder, by the pipe *e*, the area of which is diminished or enlarged by a throttle valve; if the cock *d* is moved a quarter of a turn, it will open or shut the passage to the upper or under side of the cylinder; *f*, a piston rod moving between guides, driving the crank *g h*, by means of the rod *i*; the fly *k* is placed on the axis *l* of this rod; *m*, is a double snail or eccentric wheel, which in its rotation presses down the small wheel *r*, and raises the weight *n*, by its motion on the joint at *o*; from which proceeds downwards an arm or lever *p*, and consequently, the extremity is at the same time moved outwards; this action draws the horizontal bar *o*, and carries the lever or handle *s*, (which moves upon the axis of the cock *d*,) through one-fourth of a circle. There is also a click, or ratchet-wheel on the axis which is coiling during the passage of the bar *o* outwards, and does not then act to move the steam-cock; but when the extremity *x*, of the snail, touches the wheel, the piston will then be about the top of its stroke, and the wheel *r* suddenly rises into the concavity of the snail; this causes the horizontal bar to move the steam-cock, which turns the steam upon the top of the piston, and also affords a passage for the steam to escape from beneath the piston; every stroke of the piston whether up or down produces this action.

There were some other adjusting contrivances introduced, but which, from the small scale of the figure, could not be exhibited with clearness, and are therefore omitted; the water, for instance, for the supply of the boiler, was heated before its introduction, by the steam which had moved the piston, passing under a false bottom, perforated with small holes; a portion of it so heated, was

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driven into the boiler at every revolution of the fly, by means of a forcing pump *.

When Trevithick and Vivian produced a vacuum, and worked their mechanism by high-pressure steam, they injected the "water above the bucket of the air-pump, and by this means, rendered the space usually left between the bucket and the foot-valve unnecessary, and thus perfectly excluded the admission of any elastic fluid from the injection water, into the internal working spaces of the engine."

The admission of the steam may be regulated, as in the condensing engine, by a governor. The safety valves on the boiler may be constructed on the common plan; a plug of lead, or any metallic compound fusible at a given heat, may be inserted into the boiler, which will melt when the steam rises to a certain temperature, or when the water falls below a certain level, and let it escape into the atmosphere.

Such is the simple and powerful machine of Trevithick and Vivian; and it is but justice to these most ingenious men to observe, that the engraved figure has been selected, as being that which they gave as the illustration of their first apparatus, although much less perfect than some others which they were called on to erect afterwards; but still it exhibits in construction the most beautiful simplicity of parts, the most sagacious selection of appropriate forms, their most convenient and effective arrangement and connexion; uniting strength with elegance, the necessary solidity with the greatest portability, possessing unlimited power, with a wonderful plasticity to accommodate it to a varying resistance;—it

* Repertory of Arts, vol. iv. p. 244.

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may indeed be called, by way of distinction, THE STEAM-ENGINE.

It were extraordinary if so admirable a design offered no point to be objected to: we have seen Watt was hostile to the use of steam of a very high temperature, from an opinion of its danger, but experience has shown, that this is more imaginary than real. Contrivances to ensure safety have been multiplied; and as far as human foresight and contrivance can guard against accidents, accidents may be as effectually guarded against in an engine on this construction as in one acting by the condensing process. There is not—there cannot be, anything in its formation or action, where these are resorted to, to occasion the least ground of alarm. If the same care, therefore, be applied to a high-pressure engine, it *must* be as safe as a low pressure one; indeed, notwithstanding the operation of vulgar and absurd prejudices against its safety, and the effect this necessarily has to limit our knowledge of its properties, and also to circumscribe its use, the engine of Trevithick and Vivian may now be considered a rival, so formidable, as to justify the opinion that, at no very remote period, it may claim to divide the palm of merit with the condensing engine.

The carriage, of which this beautiful apparatus was to form a part, which also may be considered as the first successful experiment, on a great scale, to apply steam to locomotive purposes, resembled in its form those used in the common stage coaches, for the conveyance of passengers. "A square iron case, containing the boiler and cylinder, is placed behind the large or hinder wheels of the carriage, and is attached to a frame supported from the axles of those wheels. The cylinder was in a horizontal position, and the piston rod was pro-

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jected backwards and forwards in the line of the road towards the front of the carriage. Across the square frame, supported by the wheel of the carriage, an axle was extended, reaching a little beyond the frame on each side; this axle was cranked in the middle, in a line with the centre of the cylinder, and a connecting rod, passing from the end of the piston, turned this axle round, and produced a continued rotary motion of it, when the piston was moved backwards and forwards in the cylinder; upon both ends of this axle, cog-wheels were fixed, which worked into similar cog-wheels upon the axles of the wheels of the carriages, so that when a rotary motion was produced in the cranked-axle by the piston rod, the rotary motion was communicated to the axle of the larger or hinder wheels of the carriages, and these wheels, being fixed upon and turning round with the axle, gave a progressive motion to the carriage. Upon one end of this axle, was fixed a fly-wheel, to secure a rotary motion in the axle at the termination of each stroke."

The fore wheels of the carriage were of the usual form, which, turning to different angles with the body of the carriage, directed its motion upon the road; and, in cases where abrupt turns of the road required sudden changes in the direction of the carriage, the toothed or cog-wheels, on either side, could be thrown out of geer, and the opposite wheel made to drive the carriage into the proper obliquity of the road. Upon the periphery of the fly-wheel, a *brake* was attached to regulate the descent down steep hills. The contrivances to effect the requisite motions of the various parts of this machine are extremely ingenious, and considering it as the first which directed public atten-

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tion to the subject, is entitled to great commendation; but the many objections to its application upon turnpike roads, operated to prevent the patentees from carrying it into practice in the manner described in their specification; they, therefore, very properly directed their attention to its use upon rail-roads.

It was not until two years after the date of this patent (1804), that Trevithick and Vivian had opportunity to make an experiment upon the Merthyr Tydvil rail-road: the engine had an eight-inch cylinder, and the piston had a four-feet six inches stroke; it travelled at the rate of five miles an hour, and drew as many carriages as carried ten tons of iron, for a distance of nine miles, without requiring any water to be introduced into the boiler from the period of its starting until it had reached the end of its journey; the great obstacle to its introduction at the time, was the supposed want of hold, or adhesion of the wheels upon the rails, to effect the locomotion of the engine.

The persevering and ingenious Evans of Pennsylvania, who has been already mentioned, as having, some time before this period, been engaged in the pursuit of constructing a steam-waggon, appears from his narrative, which is a characteristic one, merely to have described this mechanism, and deposited the description in the office of the state of Maryland. For he admits, that he never carried the scheme into practice until some time in the winter of 1804, and then, finding that the engine he had thought of for the prime mover, was different from any he had constructed before, he gave up for a time his waggon project, and applied his engine to move a mill for grinding plaster of Paris.

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In the engraving marked EVANS, *a* is an end view of the boiler, consisting of two cylindrical tubes, the lesser inside the greater; the fire is kindled in the inner one, which serves as a furnace, and the water to be heated lies between them; the smoke passing to the other end is turned under the supply boiler *b*, to heat the water for supplying the waste occasioned by working; *c*, a supply pipe which brings the water up, and forces it into the supply boiler, at every stroke of the engine; the steam ascends the pipe, and if the throttle valve *d* be lifted to let the steam into the engine, and valves *e* and *f* be opened, the steam drives the piston *g* to the lower end of the cylinder, as it appears in the engraving, the steam escaping before the piston through the valve *f*; as soon as the piston is down, the valves *e f* shut, and *h i* open, the steam enters at *h*, to drive the piston up again, and escapes before the piston through the valve *i r* these four valves are wrought by two wheels *k l*, with cams on their sides, which strike against four levers, (not shown in the figure,) to which the stems of the valves are attached, and which open and shut them at the proper times; the motion of the piston *g* gives motion to the lever *m n*, and the rod *m o*, connected to the crank, puts it in motion, and the fly-wheel *q r* keeps its motion regular; the spur-wheels *s t*, of equal size, move the valve wheels *l k*; the lever *m n* works the supply pump *c*; thus the motion is continued. The steam, after it leaves the engine, escapes up the pipe *x x*, through the roof of the house, or into a condenser, if one be used, or through the supply boiler to heat the water; *y* a safety valve, kept down by a lever graduated like a steel-yard, to weigh the power of the steam: this valve will also lift, to let the steam escape when its power

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is too great, and if the pipe of the safety-valve be turned into the flue of the furnace, then, by lifting the valve, the ashes may be blown out of the flue. Evans found that, in an engine working ten saws, when it was put in motion with steam of the elasticity to drive one saw only, and suffer the piston to move briskly, the steam was carried off from the boiler as fast as it was generated, and fuel consumed and time spent to little purpose; but when the steam was confined, and retained in the boiler until it lifts the safety-valve with a power sufficient to drive ten saws, it will do that work all day, and consume but little more fuel; and if the working cylinder be eight inches in diameter, it will drive a pair of five-feet millstones.

This engine, it will be seen from the figure, deviates little from the condensing engine of Watt, except in the boiler, the form of which is excellent *.

* One of his first boilers was a cast iron cylinder, twenty inches in diameter, and twenty feet long, cased on the outside with wood. In other cases, he made the fire surround the cylinder, and inclosed the flue by brick work.

His boilers were made strong enough by estimation, to bear a pressure of 1500 pounds on each square inch, but he generally worked with a pressure of from fifty to one hundred pounds on the square inch. He thought, in comparing the economy of using steam at this high temperature, in an engine without a condenser, with that from 212° to 220° used with a condenser, that, by doubling the fuel, he produced sixteen times the effect. The water was supplied to the boiler by a small forcing pump: he experienced great loss of power, by using cold water as a supply, "for although it lowers the heat but little, yet as it has been shown that a small increase of heat, 30°, doubles the power, so an equal decrease reduces it a half, from one hundred and twenty pounds to sixty pounds pressure." p. 37. Evans therefore used a second or supply boiler, the water of which was heated either by the steam which escaped from the cylinder, or by passing the flue of the furnace under it; as we may suppose that cold water receives heat more freely than hot, he sometimes made his boiler in

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Evans also worked his engines with steam used expansively, and this was probably their most economical application; he raised the temperature of the vapour, to make its elasticity equal to 120 pounds on each square inch, and shut off its entrance into the cylinder when the piston had made a part of its stroke, as practised by Watt and others, with steam of the common temperature. "Thus the piston is driven by strong puffs of steam, the same as an air-gun drives its bullets, with this difference, the air-gun is soon exhausted, but the fire keeps up the power of the steam; the whole power of the steam is expended on the piston before it leaves the cylinder, except what is necessary to resist the atmosphere *."

several parts, passing the flue of the furnace through them all, and forcing the supply of water into that part furthest from the fire, to pass from the one to the other, by small connecting pipes meeting the fire.—*Young Steam Engineer's Guide*, p. 49.

* "Newcomen's invention was the first step, an enormous stride, from the simple paths of nature. Here they lost sight of the true principle described by Lord Worcester. Had Newcomen constructed a strong boiler, such as used by Savery, and applied the force of steam simply to lift the piston, and the piston to lift the pump-rod to make a stroke, and let his steam escape uncondensed, he would have performed at least treble the work with the same fuel."—*Ibid.* p. 90.

"It is evident Watt in his experiments on rotary engines, used weak steam, and placed dependence on the use of a condenser. Had he, in his experiment with Barker's mill, lessened the apertures by which the steam issued, so as to confine the steam until the power in the boiler was equal to one hundred pounds to the inch, he would have been astonished to see it revolve about one thousand times in a minute, supposing the rotary tube to have been three feet in length. My rotary tube was three feet long, the elastic power of steam about fifty six pounds to the inch; it revolved with a velocity of seven hundred or one thousand times per minute; the apertures by which the steam issued, were two-tenths of an inch in diameter; it exerted more than the power of two men, and

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This engine, however, will not bear a comparison with that of Trevithick and Vivian. But the practice of Evans, and his publication on the subject, the first which was professedly of a practical nature, has produced a general impression in favour of using steam of a high temperature in North America; and by thus dispelling the vulgar prejudice which still exists against its use in England, the foundation has been laid for the introduction of improvement, on a principle which is yet thought to be capable of a great and beneficial extension *.

would answer to turn lathes, grindstones, &c., where fuel is cheap."—*Ibid.* p. 94.

* In the same book Evans describes some other projects, from which three are selected:—the first, a mechanism similar to Amonton's wheel, suggested by a pulse glass, on which he made a rough experiment. "A hollow metal wheel was filled half full with spirits of wine, or water. After expelling the air so as to form a vacuum in the upper part of the wheel, it was closed up, so as to be steam and air tight. There were no working cocks or valves, or moving parts, except the axle, which is like that of a water-wheel. The wheel being set over a fire, with the flue confined, so as to embrace about one-fourth part of its circumference, the heat of the fire generated steam in the lower and rising quarter of the wheel, and forced the liquid to the descending and upper quarter, and the wheel turned slowly by the weight of the water being greater in the descending than in the ascending side. By using steam of 272 degrees, its power in the lower quarter will be 60 pounds to the inch, and in the upper quarter, reduced (by a small shower of cold water applied on the upper side) to 30 pounds, the water will be driven with great velocity from the lower to the upper quarter, and it will move round rapidly and with great power. He constructed a "wheel of lead on this principle, which moved slowly," and he thinks that, considering its great simplicity, and that when once filled with the spirits of wine, it would never require to be replenished, as no vapour is suffered to escape, it is the simplest and most philosophical steam-engine ever conceived." He adds, that he was satisfied with his high pressure engine, "but that if he expected *to live one hundred years longer*,

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Evans, too, had rivals to dispute even his secondary claims to invention. A Mr. John Stevens, of Hoboken, near New York, had been making experiments to apply steam of a high

and could spare the money and time, he would think it worthy of a full experiment."

The construction of his *volcanic steam-engine* is also referred to another but not so definite a date. "In our pursuit," says Evans, "of means to prevent the loss of heat which is carried up the chimney of the furnace, let us have recourse to the works of nature; view the natural volcanoes, where the fire burns without the aid of atmospheric air; where all the elastic fluid generated by the fire dissolving the fuel, and all the steam formed by the water that may occasionally come in contact with the fire, united, forms the *most terrible and powerful of all steam-engines; in which the furnace, boiler, and working cylinder are united in one, working on the simple principle of applying great elastic power;* casting up mountains and making the earth quake as she brings her strokes. To apply these principles as far as we can, we make a cylindric boiler about thirty-six inches in diameter, eight or ten feet high, with a furnace inside of it, eighteen or nineteen inches diameter; both the boiler and furnace are united to the same heads, the fire being inside of the water, and the smoke flue turned downwards through the water to the bottom, where the smoke is vented, and rises in many streams of small bubbles, that it may impart all its heat to the water to generate steam. The elastic fluid, generated by the combustion of the fuel, which we may suppose is 2000 times the bulk of the fuel, and the air used to kindle the fire, expanded by the heat to double its original bulk, unites with the increased quantity of steam, to work the engine with great elastic power. But, until we can discover a fuel that will burn without the aid of atmospheric air, or until we can find means for kindling the fire with a blast of atmospheric air, as may be the case in volcanoes, we use a forcing pump to force in air to kindle the fire. This form of engine will work with much less fuel, and be much lighter than any other; it would therefore be more suitable for boats or land-carriages. I made, continues our speculator, a small boiler on this principle, which operated favourably, but being weary of the trouble and expense of putting new principles into practice, I declined the pursuit, until better prospects open, or a more favourable opportunity offers."—*Ibid.* p. 42.

When this principle is put in operation, in addition to those

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temperature, by generating it in a boiler formed of small copper tubes, each about one inch in diameter and two feet long, inserted at each end into a brass plate; these plates were closed at each end of the pipes by a strong cap of cast iron or brass, leaving the space of an inch or two between the plates. The necessary supply of water was injected by means of a forcing pump at one end, through a tube inserted at the other end; one of these boilers six feet long, two feet deep, and four feet wide, exposed four hundred feet of surface in the most advantageous manner to the action of the fire. Stevens said his object was to form a machine

already explained, I conclude, that all the principles of nature, suited to aid us in the working of steam-engines, are taken in, excepting one, which would enable us to work a steam-engine *without fuel*, which I conceive is only to be done by plane mirrors, and, perhaps, with much less expense than may at present be supposed, (see pages 6, 11, 29.) Many may think this idea chimerical, until they discover that water exposed to the single perpendicular rays of the sun, in a suitable vessel, will soon acquire the heat of human blood, in 92 degrees, notwithstanding the constant evaporation going on, which carries off the heat as fast as generated. Experiments may determine how many single rays must be collected, to triple the heat from 92 to 276 degrees in the water, which, by the table, would produce steam of elastic power sixty pounds to the inch; this would work a very powerful engine, to raise water in hot countries for various purposes. The rays collected to a focus by a convex lens, thirty-six inches diameter, produced a far greater degree of heat than any furnace ever had. How many lenses can we suppose would be necessary to work an engine? But we need not go to the expense of lenses; one hundred plane mirrors, containing each nine superficial feet, and which might be constructed of nine small glasses, one foot each, fixed in a frame, may collect rays sufficient for a powerful engine. The time will come, when water will be raised by the heat of the sun at a very small expense. But the expense of such inventions cannot be borne by those who have the mental powers to design them; at least it is highly imprudent for them to risk it. In such cases, aid from government becomes necessary."—*Ibid.* p. 190.

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adapted more immediately to the propelling of a boat. "He tried a rotary engine, on the axis of which revolved a wheel at the stern of the boat, like a windmill or smoke-jack, but he found it impossible to preserve a sufficient degree of tightness in the packing; a second modification of his rotary apparatus, on trial, proved no better than the first. At last he had recourse to Watt's engine, with a cylinder 4½ inches in diameter and a nine inch stroke; the beam was omitted; the boiler, two feet long, fifteen inches wide, twelve inches high, consisted of eighty-one tubes each an inch in diameter; his boat was twenty-five feet long and five feet wide. This was tried in May 1804, and had a velocity of four miles an hour; after having made repeated trials with her, his son undertook to cross from Hoboken to New York, when unfortunately, as the boat nearly reached the wharf, the steam-pipe gave way, having been put on with soft solder. This boiler being damaged, the next one was constructed with the tubes placed vertically. The engine was kept going for a fortnight or three weeks, the boat making excursions of two or three miles up and down the river; for a short distance he could make it sail at a rate of not less than seven or eight miles an hour*."

In the same year, his rival constructed, for the Board of Health in Philadelphia, a machine for cleaning docks. Evans, who was a clever man with a plain name, considering that a sounding cognomen would do no harm to a simple machine, christened his mud-scraper, the Orukter Amphibolos. This was a heavy flat-bottomed boat, thirty feet long, and twelve feet broad, with a chain of buckets to bring up the mud, and hooks

*Colonel Stevens took out a patent for his boiler in England, in 1805.

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to clear away sticks, stones, and other obstacles. A small steam-engine was placed in the boat to work the buckets, having a cylinder five inches in diameter, and a stroke of nineteen inches. "It was constructed one mile and a half from the river Schuylkill; the boat was mounted on wheels, which were moved by the engine; the whole, weighing about 42,000 pounds, was moved with a gentle motion up Market Street in Philadelphia, and around the Centre Square; and he concluded from the experiment, that the engine was able to rise any ascent allowed by law on turnpike roads, which is not more than four degrees; and when the Orukter Amphibolos was launched, he fixed a simple wheel at her stern to propel her through the water by the engine; she drew nineteen inches of water; and he inferred, that if the power had been applied to give the paddle-wheel the proper motion, he could have stemmed the tide of the Delaware."

Stevens went no further with his experiment, and Evans also stopped with this exhibition; in discussing their claims, Evans declared, that he had spent two thousand dollars on his project; Stevens lamented that he had been "twenty years of his life on his, and spent twenty thousand dollars, without deriving a shilling benefit." Stevens thought some of Evans's projects were absurd: Evans retorted, "that the colonel's setting himself up as an obstacle to his improvements, had done more to perpetuate his (the colonel's,) memory than his twenty years' hard work, and the loss of his twenty thousand dollars." Be that as it may, although in their lives their schemes were opposed, our respect for their memories shall not be divided, and they shall together enjoy that immortality which our little book, we hope, will confer upon them.

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The rotary engine by Hornblower, which has already been described, is complex. His second one, though simpler, is liable to the same objection. "It has a rotary motion within itself by the actions of four vanes, like those of a smoke-jack, but formed of iron of some considerable thickness, sufficient to form a groove to hold some stuffing, for the purpose of being steam-tight during their action—they are mounted on an arbour, which has a hollow nave in the middle; the tails of the vanes are inserted into this nave, and each opposite vane is affected alike, by having a steady connexion with its opposite one; so that, should the angle or position of one of the vanes be altered, the opposite one (attached to it) will be altered likewise, and they are not set in the same plane but at right angles to each other. If we conceive these vanes to be held in a vertical position like the sails of a windmill, when one vane is flatly opposed to the wind, the opposite vane will present its edge to it; and this they are constantly doing in their rotation, on their common arbour, and the steam acts against the vane on its face in propelling it into action, for about the quarter of a circle, or 90°, in the box wherein it acts, and then it instantly turns its edge to the steam, while at the same time another vane has entered the working part of the box, and the rotation proceeds without interruption." Doctor Gregory observed, that in this mechanism, as the stuffed parts (or those which move and require to be made steam-tight) are of great extent, with regard to the magnitude of the machinery, and exhibit rapid variations of shape, they would be found difficult to keep in order.

Trevithick seldom loaded the safety-valve of his engine with a weight beyond three or four atmospheres. But a Mr. Wilcox of Bristol thought the

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vapour might be raised to a temperature having a pressure of ten or twelve. High-pressure steam, however, was in no instance more skilfully or economically applied, than by Mr. Arthur Woolfe of Cambourne in Cornwall. He operated with vapour of a temperature as high as Trevithick, but instead of permitting it to escape into the atmosphere after it had elevated the piston, he introduced the steam into a cylinder of much greater size, (also fitted with a piston,) which communicated with a condenser. The high-pressure vapour, as it escaped from the smaller cylinder, expanding in the larger cylinder, raised its piston, into a vacuum made on the other side of it. And as the steam acted alternately on both sides of the smaller piston, it was also introduced both above and below the piston in the larger cylinder.

The expansive property of steam, which was applied so skilfully in this engine, was, as has been described, used in almost all of his engines by Watt, and now that his monopoly had expired, it was also used by others. And Falck and Hornblower also, had even employed its action in two cylinders. But neither Watt nor his followers raised the vapour beyond three or four pounds above the pressure of the atmosphere. Woolfe began where Watt ended.

In carrying the modification into practice, Woolfe informs us, he was led to observe the law of the expansion of elastic vapour, at very high temperatures, and he found that steam, for instance, having an elasticity of four or five pounds above that equal to the atmospheric pressure, would expand to four or five times its bulk, and still preserve a force equal to that of the atmosphere; and that vapour, equal to resisting five, six, ten, twenty, or one hundred pounds above

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the pressure of the atmosphere, would expand into five, six, ten, twenty, or one hundred times its bulk, and still balance the atmosphere, without receiving any additional supply of heat.

This property, therefore, influenced the proportions of his cylinders; if he used steam of five or ten pounds above the atmospheric pressure, the second cylinder was made five or six times larger than the other.

Experience, however, soon sobered the hopes that were raised by what was called a discovery. In fact, Woolfe himself was among the first who observed the fallacy; and it is quite certain, that in all his after-practice, he was guided by a rule, very different from that which has been stated, and he proportioned his cylinders, so as to allow the steam to expand into double its bulk, for every ten or twelve pounds which it could support above the atmospheric pressure; and he also found that the economy of allowing the expansion to proceed beyond eight or nine times the primitive bulk, was problematical.

It is now, by experiment, put beyond a doubt, that this mode of using a second cylinder produces a very considerable saving of fuel; in some cases which have been detailed, it amounts almost to a fourth, even when the comparison was made with one of the condensing engines in the best working condition.

The mechanism will be easily understood, by referring to the diagram of Hornblower's engine.

To diminish the expense of boring the cylinders, they were recommended, by Mr. Job Rider, to be lined with a softer metal, and to be finished by what is technically called draw-boring. Rider also made the piston rod hollow to serve as an eduction pipe, and regulated the admission of steam

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to the cylinder, by a weight wound up on a drum or barrel, which received its motion from a series of wheels. The motion of the barrel draws up this weight, which, being attached to the end of a lever connected with the steam valve, opens or shuts it, as it may be adjusted. The opening of the valve is formed conical, having its smaller end nearest the boiler, and the valve itself is a corresponding portion of a cone, which is advanced into its seat, or withdrawn, to diminish or enlarge the steam-way. Mr. William Deverel, who, it also appears, was aware of the fallacy of Woolfe's statement, recommended that the cylinders should have the proportion of one to three, if the steam in the boiler was equal to forty-four pounds on each circular inch; and he also considered, that after the steam had raised the small piston, it should be conducted into a separate vessel to expand, before being admitted to act on the piston in the large cylinder.

The manner Mr. James Boaz, of Glasgow, prevented the cylinder, containing the steam, from being cooled by the water which was raised into it, was to make the steam, which acts on the piston *a*, press the mercury beneath it, (indicated by a darker shade) up the pipe *b*, and by its motion force the water through the pipe *c*, into the reservoir. When the mercury has been nearly all expelled from the cylinder, the steam-cock *e* is shut, and the air-cock opened, the vapour escapes into the atmosphere, and the weight of the mercury raises the piston in the cylinder, and this leaving a vacuum in the pipe, the pressure of the atmosphere raises the water through *h* to replenish it.

In Mr. William Trotter's steam-wheel, *a* is an immoveable cylinder, in which another cylinder

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b revolves on its axis: a piston *c* placed on its circumference, in its rotation, fills the space between it and the outer vessel; *d* is an eccentric cylinder, having an aperture in its circumference through which the piston protrudes. In its revolution, a point of the periphery of the eccentric cylinder always touches the surface of the steam case, so as to form a steam tight division between the two sides of the piston or slider. When steam is introduced behind the piston, all the space on the other side is open to the condenser, and the inner cylinder is carried forward. The eccentric cylinder being also carried round by the piston, always forms, at the point of contact, the separation between the vacuum and the steam. It is not known whether this clever thought was ever carried into effect; a later speculation—the founding of the magnificent Bazaar in Soho Square, where the most benevolent purpose is seen directed by the finest method—has conferred on the author of this steam-wheel a wide and enviable celebrity as a practical philanthropist.

Mr. Andrew Flint's scheme is a modification of Bramah's first idea; the novelty is produced in the valves. The outer cylinder is fixed, and the inner cylinder, which revolves, is divided into two compartments, one of which communicates with the boiler, the other with the condenser, by a hollow axle. The two valves *c*, *d*, are each formed of a portion of a cylinder, and they are moved by a mechanism on the outside of the fixed cylinder being attached to their axes, by which they are shut and opened by the motion of the inner cylinder. The action is the same as Watt's, the steam being introduced through the opening *e*, fills the space between the valve *c* and the piston

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which is carried forward to beyond the valve *d*; it is then turned round so as to come into contact with the revolving cylinder, at the same time that the other valve is turned into its recess to allow the piston to pass over it, when it is again placed in the position shown in the drawing.

The amended projects of Mr. Wilcox of Bristol, with the exception of one scheme, are nearly the same as Watt's and Bramah's, the one forming the exception is the least practical of any, and more complex than them all. By means of short levers, and a rack and pinion, the piston is moved on a hinge, so that in passing the abutment valve, (which thus requires to be opened only to a half of the width of the piston channel,) it is moved nearer to the surface of the revolving cylinder, and is then drawn into its first position; the abutment valve is then moved outwards, and the rotary motion is continued.

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CHAPTER TWENTY-TWO.

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SOON SHALL THY ARM, UNCONQUERED STEAM! AFAR
DRAG THE SLOW BARGE, OR DRIVE THE RAPID CAR;
OR, ON WIDE WAVING WINGS, EXPANDED BEAR
THE FLYING CHARIOT THROUGH THE FIELDS OF AIR.

Darwin.

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THERE is probably no one, whose name is associated with the history of this mechanism, and whose labours have received so large a share of applause, appears to have less claim to notice as an inventor, than Robert Fulton.

His father was a poor Irish labourer, a native of Kilkenny, who emigrated to Pennsylvania, where Robert was born in 1765; and it was his misfortune, when he was little more than three years old, to lose, by the death of his father, even the slender protection which this homely lot in life afforded. In the village school he was taught to read and write a little, and in Philadelphia, he afterwards followed, with varied success, a youthful partiality for drawing and mechanics; in a few years, his perseverance enabled him to rise a little above the humble circumstances of his family, and to earn a livelihood by the sale of his portraits and landscapes. His frugal habits soon enabled him to purchase a small farm in the

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neighbourhood of Philadelphia, which he settled upon his family; and coming to London in 1786, he experienced the kindness and patronage of Benjamin West, as his countryman and an artist. Under him he made some progress in design: he was clever, without giving indications of possessing a talent, that would rise above mediocrity; as an artist, he had diligence and perseverance, but he had no taste, and little invention: this was attributed to a divided, and, of course, a desultory application; for mechanics, which had always some share of his attention, soon engrossed the whole.

He spent two years near Exeter, where he became known to the Duke of Bridgewater and to the Earl of Stanhope, with the latter of whom he communicated in 1793, on the subject of applying steam to move boats; and for the following eighteen months he lived at Birmingham, where he matured his scheme for small canals. This project receiving no attention from government, he published it in 1796. The character of this book was that of its author; it contained nothing original, either in matter or manner. But from his acquirements as an artist, the engravings were superior to those usually given in similar books; and, as exhibiting industry, was considered for a young man to be a respectable production *.

* In this treatise he attempts to prove, that small canals, navigable by boats of little burden, were preferable to canals and vessels of the large dimensions then in use; an opinion, of which the ruinous fallacy is confirmed by every day's experience, and the small returns received, in the majority of instances, from the immense sums expended in excavating and preserving some of this species of navigable ditches in England. "To continue traffic over mountainous countries, he proposed inclined planes, upon which vessels and their cargoes, navigating the canal, should be raised or lowered

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He received, in 1794, the thanks of two societies for accounts of various projects, and he had patents for improvements on sawing marble, and making cordage, but they did not turn out productive to those who became his colleagues. In 1796 he went to France, but there his private schemes met with less regard than in England. As he was not wanting in a certain sort of judgment, he revived a project which had been often suggested, and attracted the public eye, by a proposal to blow up ships, by a machine of his invention, which "moved entirely under water, and thus he hoped to deliver France and the whole world from British tyranny and oppression*."

He applied to the Directory for pecuniary assistance: he was referred to the Minister of Marine, who pronounced the project impracticable. Fulton, with his model under his arm, again presented himself to the Directory; and the persons whom they named to inspect it gave an opinion in its favour, but the inexorable Minister of Marine finally rejected it. Three years had thus been wasted, when Fulton offered his model

from one level to another; or by lifting or lowering the boat and her freight perpendicularly, by machinery, which was to be moved by the power of water taken from the superior height, and applied to a water wheel; or by the weight of a body of water received into a coffer, which was to move in a direct line between the higher and lower level, through a perpendicular shaft, or well, made in the earth for that purpose; and, in another place, he proposes to pass over a valley, from one summit to the other, by double inclined planes. In these projects he only claims the perpendicular lift, and the connexion of the inclined planes with machinery, as new ideas."—*Colden's Memoir*, p. 15.

* "His first experiment, 1797, made on the Seine, (in company with Joel Barlow, with whom he lived for seven years,) was to impart to carcasses of gunpowder a progressive motion under water, and there to explode them. He was disappointed in this machine."—*Ibid.*, p. 28.

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to the Batavian Directory : to the heavy Dutchmen it appeared as impracticable as to their lighter neighbours; and M. Vanstaphast, an opulent citizen, who had a better opinion of it than his colleagues, after disbursing the expenses of several trials, also gave it up in despair.

From Napoleon Bonaparte, after his elevation to the Consulate, he at last succeeded in obtaining money to make an experiment on a large scale at Havre, in the winter of 1801. And in sailing between that and Brest in the following year, he amused himself by alarming the gunners on some parts of the coast, by plunging his nautilus under water, and then re-appearing at some little distance; "but this amusement was all that his patrons had for their money." At Brest, however, he succeeded in immersing his nautilus to the depths of five, ten, and twenty-five feet, remaining under the surface of the water for an hour*. In another ex-

* "During this time they were in utter darkness. Afterwards he descended with candles, but found a great disadvantage from their consumption of vital air. He next fitted, near the bow of his boat, an aperture, one inch and a half in diameter, with glass, and he found this admitted light sufficient to enable him to count the minutes on his watch. Finding he could descend to any depth, and rise to the surface with facility, his next object was to try her movements as well on the surface as beneath it. His boat had one mast, a mainsail, and jib. He weighed anchor and hoisted sail, (July, 1801,) there was only a light breeze, and, therefore, she did not move on the surface at more than the rate of two miles an hour; but it was found she would tack and steer, and sail on a wind, or before it, as well as any common sailing boat. He then struck her mast and sails, and perfectly to prepare the boat for plunging required about two minutes. Having plunged to a certain depth, he placed two men at the engine, which was intended to give her progressive motion, and one at the helm, while he, with a barometer before him, governed the machine, which kept her balanced between the upper and lower waters. He found that with the ex-

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periment, he moved about the fifth of a mile under water; and in a subsequent one, accompanied by three other persons, by means of a globe, having about a foot of cubic capacity, and in which he had condensed air under a pressure of two hundred atmospheres, they remained under water for several hours *.

Having acquired some practice in sub-marine navigation, he was allowed to demolish an old brig in Brest Harbour; and during the same summer he anxiously sought to test his art on some English ships, which daily advanced to the Roads, when once, as he was on the point of attaching his "infernal machine" to a man-of-war, "it fortunately changed its position and escaped from the threatened annihilation.

Bonaparte now turned a deaf ear to his applications for further assistance, considering him to be a quack and a sharper, whose enterprises were only means to supply himself with money †. Ful-

ertion of one hand only he could keep her at any depth he pleased; the propelling engine was then put in motion, and on coming to the surface he had moved about five hundred yards; he then again plunged, turned her round while under water, and returned to near the place he began to move from: this he did several days successively. He found that the boat was as obedient to her helm under water, as any boat could be on the surface, and that the magnetic needle traversed as well in the one situation as in the other."—*Colden*, p. 34.

* "He descended to the depth of five feet; at the expiration of an hour and forty minutes he began to take small supplies of *pure* air from his reservoir, and he did so, as he found occasion, for four hours and twenty minutes; he then came to the surface, without having *experienced any inconvenience* from having been so long under water."—*Ibid.*, p. 35.

† "Bonaparte, dont le goût pour les innovations diminuait à mesure que son pouvoir augmentait, avait déjà cessé d'attacher aucun prix aux inventions sous-marines; et il traitait

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ton, more fortunate in his appropriations, having made himself acquainted with Panoramas before leaving England, established the first of that kind of exhibition at Paris; in a pecuniary view, this speculation more than answered his expectations.

It was during his journey from London to Paris, that he was introduced to Doctor Cartwright, then residing in the neighbourhood of Dover. The Doctor explained to him a mechanism to move vessels by steam, and he drew a plan of it, in the presence of some of his family, which he presented to Fulton, expressing his regret, that his circumstances at that time were not so favourable as to enable him to be at the expense of making the experiment. The Doctor's idea was not forgotten, when, during the state of incertitude with regard to his nautilus, Fulton turned his attention to propelling boats by a steam-engine.

Soon after his arrival in Paris, Fulton had formed a friendship with Mr. Robert Livingstone, then minister from the United States to the Court of France. In their conversations, this gentleman communicated to Fulton his opinion on the importance of steam-boats to their common country, informed him of what had been attempted in America, and his resolution to resume the pursuit on his return, and advised Fulton to turn his mind to the subject. It was agreed between them to embark in the enterprise, and immediately to make such experiments as would enable them to determine how far, in spite of former failures, the object was attainable; and to Ful-

leurs auteurs d'extravagans, on d'imbéciles, et ajoutait, à l'égard de Fulton, que cet Americain était un charlatan, un escroc qui voulait seulement attraper de l'argent."—*Montgery*, p. 241.

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ton, says the Chancellor, was left the principal direction of these experiments.

Among the schemes which Fulton thought of, but discarded, was that of Franklin, and those by Fitch, as well as Rumsey. By paddles and duck-feet oars, he saw it was impossible to drive a boat six miles an hour, and he thought it was to such defective applications of power, and not to a want of it in the engine, that all experiments had hitherto failed.

Endless chains, with resisting boards upon them as propellers, appeared to him greatly preferable to any other method which had been tried; and as he was desirous of proving their effect by actual experiment, for which he wished for more retirement than the waters near Paris would afford, he accompanied Mrs. Barlow, who had been ordered by her physicians to Plombieres; and on a little rivulet, which runs through that village, he made a course of experiments with a set of models he had constructed for the purpose: the results of these gave him strong assurances of success.

During the time Fulton was engaged in these experiments, a M. des Blancs, whose boat on the Soane has already been noticed, deposited a model of his apparatus in the Repository of Machines at Paris. In this he used a horizontal cylinder, by which endless chains, with resisting boards upon them, or what he called chaplets, were to be worked from stem to stern alongside of the vessel.

From Fulton's report of his experiments at Plombieres, on models of his own invention, it was understood, says Livingstone, that *he* had developed the true principles upon which steamboats should be built, and for the want of knowing which, all previous experiments had led to no

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useful result. But as many things, which were apparently perfect when tried on a small scale, had failed when practised on a large one, they determined to go to the expense of building an "operating boat" upon the Seine.

During the construction of this vessel, Des Blancs called the public attention to Fulton's operations as an invasion of his patent right; "and he also addressed a remonstrance to Fulton himself on the subject. In reply the American explained, that his plan differed materially from Des Blancs', for his boat was to be propelled by wheels, not by chains. He also, at the same time, communicated to Des Blancs his own experiments with the chaplet mechanism and paddle wheels; and informed him, that the result decided him to adopt the latter. Fulton concluded by offering his rival a share in the advantages of the discovery which he had made, if he would bear his proportion of the expense. But no notice was taken of this offer, or even of the letter*.

Livingstone and Fulton's experimental boat was completed early in the spring of 1803—"And they were on the point of making an experiment with her, when one morning as Fulton was rising from a bed, in which anxiety had allowed him but little rest, a messenger from the boat, whose precipitation and apparent consternation announced that he was the bearer of sad tidings, presented himself to him, and exclaimed—'Oh, sir, the boat has broken in pieces, and gone to the bottom!'"—For the first time in his life he felt a vivid emotion of despondency, but this was only for a moment. On examination he found that the boat

* *Colden*, p. 159.

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had been too weakly framed to bear the great weight of the machinery, and in consequence of an agitation by the wind on the preceding night, what the messenger had represented had literally happened. By great exertions the parts were raised from the bottom, and the greater part of the boat was rebuilt. Her length was sixty-six feet, and her width eight feet. Fulton's experiment drew a great concourse of spectators, in August, 1803; the wheels and other machinery acted according to his expectations, although her speed was not so great as he calculated upon her machinery producing *. Such entire confidence

* "Blasco de Garay, a sea captain, exhibited to the Emperor and King Charles V., in the year 1543, an engine by which ships and vessels of the largest size could be propelled, even in a calm, without the aid of oars or sails.

"Notwithstanding the opposition which this project encountered, the Emperor resolved that an experiment should be made, as in fact it was, with success, in the harbour of Barcelona, on the 17th of June, 1543."

"Garay never publicly exposed the construction of his engine, but it was observed at the time of his experiment, that it consisted of a large caldron or vessel of boiling water, and a moveable wheel attached to each side of the ship.

"The experiment was made on a ship of 209 tons, arrived from Calibre, to discharge a cargo of wheat at Barcelona; it was called the Trinity, and the captain's name was Peter de Scarza.

"By order of Charles V. and the Prince Philip the Second, his son, there were present at the time, Henry de Toledo, the governor, Peter Cardona, the treasurer, Ravago, the vice-chancellor, Francis Gralla, and many other persons of rank, both Castilians and Catalonians; and among others, several sea captains witnessed the operation, some in the vessel, and others on the shore.

"The Emperor and Prince, and others with them, applauded the engine, and especially the expertness with which the ship could be tacked. The treasurer Ravago, an enemy to the project, said it would move two leagues in three hours. It was very complicated and expensive, and exposed to the constant danger of bursting the boiler. The other commissioners affirmed, that the vessel could be tacked twice as

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did he and his associate acquire from this trial, that he writ instructions to Watt and Bolton, to prepare a steam-engine for him, and which was to be sent to New York, to which place he prepared to return, in order to introduce his invention on the American waters*; and soon afterwards Livingstone succeeded, by means of his friends at New York, in having his privilege of navigating all the waters of that State by steam, which had

quick as a galley, served by the common method, and that at its slowest rate it would move a league in an hour.

"The exhibition being finished, Garay took from the ship his engine, and having deposited the wood work in the arsenal of Barcelona, kept the rest to himself.

"Notwithstanding the difficulties and opposition thrown in the way by Ravago, the invention was approved; and if the expedition in which Charles V. was then engaged, had not failed, it would undoubtedly have been favoured by him. As it was, he raised Garay to a higher station, gave him a sum of money (200,000 maravedies) as a present, ordered all the expenses of the experiment to be paid out of the general treasury, and conferred upon him other rewards.

"Such are the facts collected from the original registers preserved in the Royal archives at Samancas, and among the public papers of Catalonia, and those of the Secretary at War, for the year 1543."

This remarkable statement appears as a note in the first volume of original papers relating to the voyages of Columbus, lately published in Spain, by one of the Secretaries of the King, and printed at the Royal Press, was communicated to the author, in a letter from Thomas Gonzales, dated at Salamanca, 27th August, 1825; and it would seem he had recently consulted the public records to which he refers. The editor of the *Franklin Journal*, from whom this extract has been made, observes, "when the 'Public Records' shall appear in an *authentic form*, their evidence must be admitted; *until then* he should not be inclined to commence the history of the invention of the steam-boat, so far back as 1543. For circumstantial as the account is, it seems to have been written since the days of Fulton."

* "It is said, that the shore of the Mississippi, and of the rivers which flow into it that are navigable for steam-boats, are equal to an extent of fifty thousand miles."

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become obsolete, re-granted to Fulton and himself, for a period of twenty years.

Fulton, whose nautilus had never risen fairly to the surface, found means of communicating his experiments to the Earl of Stanhope; and coming to England, through his lordship's influence, Fulton, received permission from the government to turn the scheme Bonaparte so much despised, against himself. Fulton was sent to the fleet stationed off Boulogne, and had there an opportunity of making an experiment on two French gun-boats, but the nautilus exploding before the proper time, did not even frighten those whom it was sent to destroy. Although the impression against the scheme was decisive, yet, by the influence of his noble patron, he was permitted, a fortnight afterwards, to make another experiment on an old vessel lying in Walmer Roads," and with the assistance of Sir Home Popham, and two boats' crews, succeeded, after an unresisted attack of two days, in blowing up this poor old carcass *."

This failure again left him at leisure to attend to his steam-boat project, for which Bolton and Watt had nearly constructed an engine on their peculiar principle, but with some modifications to adapt it to propel a vessel; during its progress, he visited Scotland, and inspected Symington's steam-boat on the Forth and Clyde Canal.

Fulton remained in England until October; and, on his arrival at New York, in December, 1806, he commenced his operations to perfect his torpedoes, or submarine bombs, and to build his steam-boat; but finding, when erecting her, that the expenses would greatly exceed his

* On our side of the water, mechanics had not been idle; for Lord Stanhope had invented a submarine machine to destroy the nautilus!!

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calculation, he endeavoured to lessen the pressure on his finances, by offering a third share of his exclusive right, to navigate steam-boats in the State of New York, to some individuals, for a proportionate contribution to the expense of this experiment; but he found no one willing to aid him in this enterprise.

In the spring of 1807, notwithstanding the pecuniary and mechanical obstacles opposed to his project, Fulton had completed the vessel, and it was soon after launched on the East River. The engine which had been sent from Watt and Bolton, by this time had arrived, and with the assistance of the working engineers, who had accompanied it from Soho, it was fixed in the boat; and in August, 1807, Fulton had the satisfaction of seeing this celebrated vessel moved by her machinery from her birth-place to the Jersey shore. On this occasion Livingstone and Fulton had invited many of their friends to attend the first trial; "and nothing," says Colden, "could exceed the surprise and admiration of all who witnessed the experiment. The minds of the most incredulous were changed in a few minutes—before the boat had made the progress of a quarter of a mile, the greatest unbeliever must have been converted. The man, who, while he looked on the expensive machine, thanked his stars that he had more wisdom than to waste his money on such idle schemes, changed the expression of his features as the boat moved from the wharf and gained her speed: his complacent smile gradually stiffened into an expression of wonder—the jeers of the ignorant, who had neither sense nor feeling enough to repress their contemptuous ridicule and rude jokes, were silenced for the moment by a vulgar astonishment, which deprived them of the power

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of utterance, till the triumph of Genius extorted from the incredulous multitude, which crowded the shores, shouts and acclamations of congratulations and applause." Though her performance far exceeded the expectations of his friends, Fulton perceived that there was an error in the construction of her water-wheels—he lessened their diameter, so that they did not dip so deep into the water, and it was manifest that the alteration had tended to increase the speed.

"This famed vessel, which was named the Clermont, soon after sailed for Albany; and, on her first voyage, arrived at her destination without any accident. She excited the astonishment of the inhabitants of the shores of the Hudson, many of whom had not heard even of an engine, much less of a steam-boat. There were many descriptions of the effects of her first appearance upon the people of the banks of the river. Some of them were ridiculous, but some of them were of such a character as nothing but an object of real grandeur could have excited. She was described by some, who had indistinctly seen her passing in the night, to those who had not a view of her, as a monster moving on the waters, defying the winds and tide, and breathing flames and smoke."

"She had the most terrific appearance from other vessels, which were navigating the river when she was making her passage. The first steam-boats, as others yet do, used dry pine wood for fuel, which sends forth a column of ignited vapour, many feet above the flue, and whenever the fire is stirred, a galaxy of sparks fly off, which in the night have an airy, brilliant, and beautiful appearance. This uncommon light first attracted the attention of the crews of other vessels. Not-

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withstanding the wind and tide were adverse to its approach, they saw with astonishment that it was rapidly coming towards them; and when it came so near, as that the noise of the machinery and the paddles were heard, the crews, in some instances, shrunk beneath their decks from the terrific sight; and others left their vessels to go on shore, while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster which was marching on the tides, and lighting its path by the fires which it vomited *."

In this first voyage the distance run was about one hundred and fifty miles, which was accomplished in thirty-two hours, giving a speed of about five miles an hour. The voyage back was made in the same time; and both going and returning, the wind (a light breeze) being a-head, the whole was performed by the steam-engine and wheels. The voyagers overtook many sloops and schooners beating to windward, and parted with them as if they had been at anchor.

This triumphant experiment established Fulton's reputation; and, soon after, this fine vessel plied between New York and Albany, as a passage-boat, and her success raised Fulton to a well-merited independence.

"It would have been an extraordinary circumstance if her machinery had been like the men of Cadmus, perfect at its birth; and it would have been quite as extraordinary, if its effects could not have been produced by an arrangement or combination of its parts, not precisely that adopted by Fulton †."

* *Colden*, p. 173.

† The dimensions of the CLERMONT were—*length of boat*, 133 feet; depth, 7 feet; breadth, 18 feet. The *boiler* was

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Yet the men who refused to share in his chances of gain, when he offered them for sale, were greedy of his profits, and envious of his fame, after he had established, by an experiment of an immense cost, the practicability of the invention, and seizing upon some obvious and trivial defects, for which they proposed a remedy, or suggested some slight variations in the arrangement of the machinery, on these grounds contested his right as an inventor, and put forth claims to a share in his hard-earned emoluments. Another source of annoyance arose from the prejudices of those who considered the introduction of steam-boats on the American waters destructive to the interests of the common navigators: by these Fulton was spoken of as if he had introduced some project baneful to society; and the Clermont became the object towards which their hostility was directed. She was often intentionally run foul off to produce damage; and this spirit of hostility had shown itself so openly, that the Legislature passed a law to punish, by fine and imprisonment, all those who made wilful attempts to destroy her *. But notwithstanding

20 feet long, 7 feet deep, and 8 feet broad. The *steam-cylinder* 2 feet in diameter; and the *piston* made a stroke of 4 feet. The diameter of the *water-wheels* was 15 feet, the bucket 4 feet long, and dipped 2 feet into the water. The burden 160 tons. Built 1806.

The CAR OF NEPTUNE, built in 1807, carrying 295 tons, was 175 feet long, 8 feet deep, and 24 feet wider. The *boiler* 18 feet long, 8 feet deep, 9 feet broad. *Steam-cylinder* 33 inches in diameter: the *piston* had a stroke of 84 inches; the *water-wheels* 14 feet in diameter; 4 feet long buckets, which were immersed 2 feet 4 inches in water.

* The Legislature of New York were so fully convinced of the great utility of the invention, and of the interest the public had in its encouragement, that they made a new contract (1808) with Livingstone and Fulton, by which the term

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these demonstrations of animosity, the confidence of the public in her performances was increasing, and the Clermont continued to run, loaded with passengers, for the remainder of the summer. To provide accommodation for an anticipated increase of voyagers, she was enlarged in her dimensions in the winter of 1808.

Fulton again renewed his experiments with his nautilus and torpedoes, but the opinion of his countrymen was as decidedly against them, as that of those persons who had witnessed his trials in France and England.

Divesting his labours, of all the claim he makes for them, of being undertaken with a patriotic motive, when compared with his countryman Oliver Evans, a labourer also in the same vineyard, he falls greatly below him in practical knowledge, as well as in the power of invention. There was great perseverance in both. Neither hesitated to talk of themselves and their works, in terms which had been used in a better taste by their friends or admirers. But Evans, viewed as one whose ingenuity will probably be less considered than the success of his enterprising contemporary, had a sturdy ingenuousness, which it was one of the greatest blemishes in Fulton's character that he did not possess. But yet Fulton's merit is still of no ordinary kind. Under circumstances where others had given way to despondency, and had sunk under their repeated failures, he persevered in experiment until he produced a successful result; and the splendid

(originally twenty years from 1807) of their exclusive right to the profit of all steam-boats on this peculiar plan, which should navigate the waters of that State, should be extended five years for every additional boat they should build, provided the whole term did not exceed thirty years.

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effects which have arisen from his practical introduction of steam-navigation has given him a well-merited claim to rank foremost with those whose enterprise has conferred a lasting benefit on his country.

It is not clear whether it was after the erection of this vessel, that Fulton had some correspondence on the subject of steam-boats, with an individual whom we have already mentioned with approbation. "Fulton," says Mr. Bell, "had occasion to write to me about some plans of machinery in this country, and begged the favour of me to call on Mr. Miller of Dalswinton, and see how he had succeeded in his steam-boat scheme; and if it answered the end, I was to send him a drawing and full description of it, along with my machinery. This led me to have a conversation with Mr. Miller, and he gave me every information I could wish for at the time. I told him where, in my opinion, he had erred, or was misled by his engineer, and at the same time, I told him that I intended to give Fulton my opinion on steam-boats. Two years thereafter, I had a letter from Fulton, letting me know that he had constructed a steam-boat, from the different drawings of machinery that I had sent out, which was likely to answer the end, but required some improvement upon it *."

Rumsey's plan of propelling a vessel by means of the re-action of a stream of water †, was again

* *Caledonian Mercury*, 1816.

† "Mr. Watt informed Buchanan that he tried a pump similar to Linaker's, to propel a vessel for Rumsey, but its effect in moving a boat was very small. Watt, however, justly observed, that Rumsey applied the power to great disadvantage, because he forced the water through a very small

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made the subject of experiment by Mr. William Linaker, master shipwright in Portsmouth Dock-yard. From some memorandums, found among his papers after his death, it appears that as early as 1793, he had made a set of experiments on propelling a vessel by machinery, but it was not until 1808 that he applied for a patent. Linaker had two plans, one was to work pistons horizontally, in pumps drawing water in at the bow, and discharging it at the stern of the vessel: the other was to work a vertical pump in the middle of the vessel, also drawing the water in at the bow, and expelling it at the stern. This idea he proceeded to put into practice on a scale of some magnitude, and had a steam-engine constructed by Murray and Wood. "But, I am uncertain," says Buchanan, "whether he lived to try it on board his boat." When the second plan was tried, the motion of the vessel was far from being uniform, and it went by jerks at each stroke of the pump; this irregularity Buchanan thought might have been remedied by attaching air-vessels to the pumps, and the stream of water would, by their aid, have been made continuous. It was the opinion of the same excellent mechanic, that if the pumping

pipe, and that the pipe should have been as large as the pump barrel."

"From one of Linaker's papers without a date, it would appear, that he had tried a boat on this plan. It was a heavy boat, 31 feet long, 6 feet wide; and although it had but one trunk, which was much against the uniformity of its motion, it moved nearly 4 miles an hour, with 8 men working 30 strokes per minute; 6 men working 25 strokes per minute, moved it at the rate of 3 miles an hour; the length of the bucket stroke was 6 feet, inside of trunk 5 inches by 15 inches: when the valve was open, the water passage was very free, the metal being cast thin; the trunk had its sides parallel from end to end." BUCHANAN *on Steam-Boats*, p. 55.

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principle were as effective as paddle wheels, it would be a preferable mode in rough water.

After Linaker's death, a partial but imperfect trial of a similar apparatus was made on the Thames. The steam-engine had no piston, but drew in the water, and expelled it on the principle of Savery's engine; an application, by the way, of this form of machine which of all others appears the most injudicious.

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CHAPTER TWENTY-THREE.

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"SOME INVENTORS DO THINK IT NECESSARY TO KEEP THEIR DISCOVERIES VERY SECRET, FOR FEAR OTHER PEOPLE IMITATING THEM SHOULD SHARE IN THEIR PROFITS. THIS FALSE OPINION HATH BEREAVED THE WORLD OF SEVERAL GOOD SECRETS, AND THE INVENTORS HAVE ALSO BEEN DEPRIVED OF ALL THEIR PROFITS, BECAUSE THEY WERE AFRAID TO LOSE A PART OF THEM."—*Papin.*

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In the variety of attempts, which have been described, to construct a steam-wheel, and several of them made on a scale of magnitude, even those which promised considerable advantage over reciprocating engines were gradually abandoned by their authors, and recourse was had to machines on the usual model. It is not, however, quite clear, whether these repeated failures arose from a want of perseverance on the part of their inventors, in mastering, probably, some niceties of construction which were essential to their action, and which perseverance in experiment could alone discover and remove; or whether failure might be traced to the adoption of a favourite but defective form.

In the earlier attempts, it is quite possible to conceive that the fibrous nature of the material employed to make the piston steam-tight, would, under many circumstances, render any attempt to produce a rotary engine abortive; for in the

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revolution of the piston, the packing would infallibly be torn out of its position, and thus destroy the trim of the engine. But after Cartwright had proposed his metallic packing, this objection was in part removed. The "abutment valves" also, as they are called, were in almost all the projects formed like hinges, and no attention appears to have been paid, except by Bramah, to assist their action, or to make it more gradual by means of springs: the effect of the vibrations of the parts, in increasing the difficulty of making them steam-tight, does not yet appear to have been noticed by any one.

A steam-wheel, on a peculiar construction, was tried at Soho, about 1806. "A remarkable incident," says its author, "occurred on that occasion. Whilst the engine was at work, Mr. Bolton was called out of the room; on his return he informed me, that he had been requested by an American gentleman, to give his advice on the same invention, and that one of us must have borrowed it from the other. This, however, proved not to be the case; and on a more minute examination, there appeared a considerable difference in the mode of constructing the American engine, which was, I think, the best of the two, if used with water only. These engines are so simple in principle, and so cheap and durable, that on many occasions the anonymous inventor thinks they might be applied with great advantage. The power of them is derived from the tendency of light bodies to float when immersed in heavy fluids, or, to speak more correctly, of the heavy fluids to displace them."

The wheel shown in the figure is placed in heated mercury, or a mixture of eight parts of bismuth, five of lead, and three of tin, which is fluid at the

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temperature of 212°; each of the cells, *a*, *b*, &c. in the series, into which the circumference of the wheel is divided, is connected by a pipe 1, 2, &c. which radiating to the centre terminates in the nave *e*. The steam pipe *f*, which has a perforation *g*, is inserted into this hollow nave, and the wheel turns upon it as an axle; in its revolution each of the radiating pipes comes opposite the perforation in the steam-pipe, and the cell with which it communicates is then at the lowest part of the circumference: the vapour forces the fluid metal out of the cell through the perforation or valve *i*, and the preponderance of the cells on the opposite portion of the circumference raises the cell filled with vapour, and brings another filled with the metal opposite to the perforation in the steam-pipe,—as each cell approaches the highest point in the path of its revolution, the steam escapes into the space above the fluid; "and where the expansive force only is used, the steam escapes from the top through *h*; but if this be connected with a condenser and air-pumps, as usual, the full power will be obtained with the metallic fluids. Each cubic foot of steam when moving in water will give sixty pounds in power; in the metallic mixture about six hundred pounds, and the velocity with which this supply can be afforded, and the height it can rise, will give the remaining elements for calculating the power of the engine. "The metallic mixture is subject to oxidation by the hot water, but it may be easily restored again, by melting the oxide under tallow. When the water only is used, the whole machine may be made of wood, in the form of a common bucket water-wheel: a steam-pipe is introduced through the bottom of the trough, just under the side of the wheel, where the buckets are inverted when

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they become filled with steam in succession, and thus a stream of steam effects as much, bulk for bulk, as a stream of water*:" this was the form of the American engine.

Mr. Henry Maudslay directed his attention more to the combination of a portable and compact machine, than to the introduction of any novelty in the application of a principle, or in construction; and he succeeded in producing an engine, combining much elegance with extraordinary compactness, and without any sacrifice of power in the attainment of these advantages.

The many previous failures did not discourage Mead from attempting a new form of a steam-wheel; resembling Hornblower's in the pistons becoming alternately abutment valves, but which are brought to rest and fixed by a mechanism on the outside of the steam ring.

In the engraving marked MEAD, *fig.* 1, is a vertical section of the apparatus; and *fig.* 2 is a horizontal view of it; *a*, *b*, are the two pistons attached to the axles *i*, *d*, by the flat rings *e*, *f*, *g*, *h*, levers, and *i*, *k*, friction wheels moving in a grooved frame *l*, *m*, fixed on the fly-wheel *n*; steam is admitted into the hollow ring, in which the pistons move by an opening in its circumference; and by a similar opening a communication is formed with a condenser, or with the air. The axis of the engine is placed excentric with the axis of the fly-wheel; when the wheel to which the groove is fixed is turned half way round, one of the friction wheels, being laced in its axis, will remain passive; or be loosed, and the valve to which it is attached will thus be the abutment valve, while the other friction wheel, with its lever and pis-

* *Mech. Mag.*, vol. iv. p. 137.

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ton attached to it, will make a revolution round the centre of its motion; and when the revolution is completed, it will be nearly in the centre of the groove in the fly-wheel, and will then be locked, when its piston will become the abutment valve: at this moment the friction wheel, which had been locked, is disengaged, and moving towards the circumference, the piston attached to it will make a complete revolution round its centre of motion; and at the instant it has done so it will be locked in its turn, and the other piston will begin its revolution, and its friction wheel move towards the circumference, and so on.

Mead made some engines on this principle, but their fate did not vary from those which had preceded them. The great friction of the circular plates by which the pistons were attached to the axle, and their consequent wear, was, in practice, a bar to this apparatus becoming generally useful. It is inferior to Hornblower's in the circumstance of the piston moving over the perforations made for the steam and condenser pipes, but it excels the model in the means for making one of the pistons alternately become the abutment; and also in the vapour acting on the piston at a distance from the centre of motion: but, ingenious as it is, it yields to that designed by Mr. Samuel Clegg, in simplicity and portability. Taken as a whole, Clegg's may be considered as one of the most ingenious combinations which has been produced for this purpose, and although it has not been received into practice, it must be ranked as one of the most elegant machines of the period. It is to be regretted that its author, like many others, has been deterred from persevering to give it the modifications necessary to its perfection, by the great expense of

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experimental trials. The rotary part is shown in fig. 1, (engraving marked CLEGG) which is a view of the under side of the top plate of the steam chamber, supposing the under plate were removed, and looking upwards. Fig. 2, a section of the complete apparatus; the same letters refer to the same parts in both figures: *a*, *a*, *a*, are blocks of segments formed of the breadth, and fitted into a groove *b*, *b*, but of a somewhat less depth; their sides are ground flat and plain so as to make them fit and be air tight, or nearly so, and their under surfaces are made to form one complete flat surface, excepting a space taken up by adjusting screws or springs, but which are placed so far below the surface, as to let a roller pass clear of them: the bar or radius *c*, of any convenient breadth, but not more in thickness than will be necessary for its strength when it moves with freedom in the interval between the under side of the blocks and the plate *d*. To this bar is attached a roller *e*, which, when it is in motion, precedes it, having its upper surface so much higher than the upper surface of the radius, that it presses upwards against each block in succession, to raise them, and permit the radius to pass beneath it; and in order to make this raising easy and gradual, a part of the lower face of each block is rounded in the manner shown in fig. 3; the piston is fixed at the end of the radius and moves in a semicircular ring; and the abutment valve *g*, moves on a hinge, and is pressed upwards into the recess by the passage of the piston over it. When steam is therefore introduced by an aperture near *h*, the piston will recede from the elastic pressure, and the air on the opposite side of the piston will pass through the spaces *i*, *i*, and during this movement, the segments being in fair bearing everywhere upon

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b, (except when raised by the roller *c*,) will keep the space tight and well closed; as soon as the piston approaches the abutment valve, it forces it upwards into the recess, and during this interval the rotary motion is kept up by the momentum of a fly wheel. After the piston has passed the valve it falls by its own gravity into its former position, and again acts to divide the steam from the atmosphere, and the steam which had urged the piston will escape by the opening. Each block or segment is of sufficient magnitude to counteract the pressure on that part of its under surface which is over the piston chamber. The space, says the inventor, through which a piston of a steam engine will generally revolve, will be about twenty feet, and the weight of the series of segments about five hundred pounds; the flat facing on which the blocks are ground is about three inches broad.

In the figures, the piston is supposed to be moved by high-pressure steam against the pressure of the atmosphere. In a third design a rotary movement was attached to a condenser; and here may be observed some ideas, estimable for their novelty and elegance. The rod forming the axis of the piston bar is prolonged downwards, and has an inclined spiral plane attached to it. The rod of the air pump is a hollow tube, having a cross bar with a wheel at each end. As the piston revolves, the inclined spiral plane which is attached to its rod in its revolution acts on the wheels on the cross bar, and moves the valves and also the air pump piston upwards and downwards. The injection water is made to fall from the upper side of the blocks, and the hot water is pumped into the well. Clegg erected some of these engines on a large scale; the objection we believe which operated against their introduction was

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the great liability of the abutment valve to get out of order.

Hitherto Bolton has been exhibited as a co-labourer with Watt, in the fabrication of condensing engines; but, although circumstances made that the most prominent, it was not the only one, nor even the greatest, of his speculations. Long before Watt was known to him his specimens of inlaid steel were unrivalled for their elegance and beauty, and his ornaments in gold, in silver, and in enamels, were admired throughout Europe. Seeking for a power to actuate the machines by which these splendid things were made, drew, as we have seen, his attention to Watt and his invention. Afterwards when his mechanism had been perfected, Bolton employed it to move presses for coining provincial tokens, when that kind of money was permitted to be circulated in England. He also struck gold and silver coin for the Russian nation; silver money for the colony of Sierra Leone; copper coin for the merchant-kings of India; and money of the same material for "the king of those kings—the king of the sea." When regal pride required the symbols of sovereign power to be formed in a national establishment—still Bolton, the incomparable worker in metal, continued to coin the money of gold, of silver, and of copper: for the machines in the royal mints, were not only formed after the model of those with which he had operated, but they were constructed in every part at Soho, and put together and afterwards superintended by engineers sent from that establishment. A complete and powerful coining apparatus was erected for the Empress Catherine at St. Petersburgh: another for the "majesty of Denmark" at Copenhagen; and a third in the

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English mint—a fourth at this time was in progress for the Emperor of Brazil. By these *self-acting coining machines* the ingots were laminated, the plates cut into pieces of the proper size—and placed under the dies, and with the assistance of a little boy only, eighty beautiful specimens of the medallic art were produced from each mould in a minute. During the entire progress of the operation, all possibility of embezzlement by the workmen was prevented, and a fruitful source of crime was also extinguished in those countries where the money was circulated; from the admirable means employed in its fabrication, a piece could not be imitated by a single artist for its current value, and without similar machinery there were parts, which the most expert coiner could not imitate at all. In former money, the genuineness of the specimen could be estimated by its weight only when an inspection satisfied us that the metal was of the standard purity. Here was a wide and fatal field, inviting the practices of infatuated men; they alloyed the metal, and by making the counterfeit have the same weight and appearance, their deception was perfect. For the first time in the history of numismatics, Bolton applied another test to money: even if the metal of which a coin was composed had been taken from the same ingot, and was of the same weight, unless the piece could be passed through a perforation of a certain size, it had not received its impress from Bolton. These coinages and mints were, however, only some of his incidental manufactures, undertaken without disturbing the routine of his establishment in its staple and more important productions. The cost of the steel trinkets, and buttons only, made at Soho, was probably equal in value to all the coin, and mints, and

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steam-engines sent from it. Some of Bolton's toys of iron far surpassed in value those formed of gold and silver.

The magnitude of the scale on which he traded, although it might excite the cupidity and envy of rivals was of subordinate importance to the public, when compared with the influence which his modes of business, and his incessant exertions, and disregard of expense in attaining the art of giving the utmost beauty to his productions, had in stimulating his contemporaries to follow him at what distance they could. In this pursuit of perfection on the one hand, and the endeavour at imitation on the other, the trade in metallic and enamelled ornaments underwent a complete revolution: from an importing country in the more expensive articles, England became an exporting one, and that under circumstances most flattering to Bolton's exertion and ingenuity: long after his productions had been brought to great perfection the whim of English trinket buyers could be gratified with foreign baubles only. Bolton, who always managed these matters with address, on the present occasion showed no falling off in his knowledge of business and of the world; articles adapted to this squeamishly refined taste were sent from Soho to the continent, whence they returned to England as the handiworks of foreign artists, in finish and in form so exquisite, as to be quite unapproachable, by plodding clumsy English artisans.

The machinery which performed all these wonders was, in itself, still more wonderful; even in the moulding and polishing of a watch chain, or a buckle, machines were put in action of the most complicated and ingenious contrivance. And, although, it cannot be said that all the

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apparatus which formed the magical display at Soho was invented by Bolton, or even designed at first for his purposes, yet his was the knowledge to direct its appropriation,—the skill to decide on its modifications, and the ingenuity to devise the links for its application in an efficient manner —surely the wish and endeavour to surround himself with a galaxy of ingenious men, to direct and assist him in his labour, was in itself an honourable ambition, and sprung from true greatness of mind,—even keeping the munificence with which he remunerated them, and the candour with which he acknowledged their assistance, altogether out of the question.

With regard to Watt, Bolton was in truth his protecting angel. But who that ever was connected with the master of Soho, could say, fortune passed by while he faultered midway from fear or languor? Even after success had produced confidence in his own powers, Watt never evinced that energy of purpose and love of business which could have carried him beyond the first steps in the race towards the goal of honour, where his colleague left him. The supine and amiable author of the condensing engine showed none of that decision of character which could have justified an observer pointing him out as one likely to form an exception to the melancholy list of men of genius, who appear to adorn and benefit society, and to become victims to its neglect, ingratitude, or injustice. Watt himself was sensible of the peculiarities of his temperament when bearing testimony to the virtues and talents of the princely Bolton. "Our friendship," says he, "continued to the close of his life. As a memorial due to that friendship, I avail myself of probably a last public opportunity of stating, that to his friendly encou-

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ragement, to his partiality for scientific improvements, and his ready application of them to the processes of art, to his intimate knowledge of business and manufactures, and to his exalted views, and liberal spirit of enterprise, must in a great measure be ascribed whatsoever success has attended my exertions."

The lassitude of a lingering disease had no effect in depressing the active habits of Bolton's mind, and he continued in his declining age to direct the varied and complicated operations at Soho. At length nature, which for years had been sinking, fell apace, and in August 1809, his magnificent spirit was quenched in death. His body was borne to its tomb, in Handsworth church, by six of his eldest workmen, and six hundred of his artisans formed the train of mourners for their friend and master.

Mr. William Chapman's steam-wheel is an improvement on Cooke's, and supplies some parts in which his was very deficient; a division between the condenser and the steam can be made by the stop or abutment *a*, and this can be tightened at pleasure from the outside, by means of a screw *c*, the valves are shut as they approach the abutment *d*, by a roller. "In the experimental engine erected at an iron work, the joints could not be kept steam tight, and the strokes of the hinged valves against the roller, were likened to those proceeding from a tilt hammer *." A second and a larger engine was given up for the same reason.

The next project differs from all previous ones, in actually producing a rotary movement, by making the common reciprocating engines (ar-

* Hebert's *Register of Inventions*, vol. iv. p. 428.

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ranged round an axis,) form a regulating body instead of a fly wheel, by weights alternately drawn to and driven from a centre, round which, a working cylinder or cylinders revolved; weights attached to the piston rod or rods, were drawn as near as possible to the centre on the ascending side, and projected outwards as far as possible from the axis on the descending side. Witty, in a second scheme, dispensed with these weights, and made the piston impel the machinery round while its own motion was both rectilineal and rotary. The most practical of his schemes for this purpose, is a clever adaptation of Mead's method, by which he engaged and then disengaged his pistons, by their axes moving in an inflexible groove.

Woolfe, some of whose improvements have already been described, suggested, that in many cases his first mechanism could be improved by using a working cylinder (similar to Papin's) having no bottom, which he would surround with a second cylinder, and fill the space between with oil. His scheme for tightening the packing of steam pistons, without removing the cover of the cylinder, is one of great practical value.

The scheme of Mr. William Onions, of Bristol, singular from its novelty, was a hollow ring moving on an axis, connected by hollow arms or spokes with passages leading into the boiler, or condenser. A metallic composition of bismuth, mercury, and lead, fusible at the temperature of boiling water, was forced by the vapour up one side of a wheel, in order to produce a preponderance over the other, on the principle of Amonton's wheel. The periphery of the wheel had two valves within it at opposite sides, but opening in the same direction, and the steam by being admitted between a valve and the fluid,

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caused that fluid to rise and pass through the next valve, so as to make one side of the wheel heavier than the other; consequently it moves partly round, by which the cocks or valves for regulating the direction of the steam are moved and varied, and the steam already in the wheel is permitted to escape through another of the arms, at the end of the hollow axis opposite to that by which it had been admitted, while a new quantity of steam, is at the same time admitted into the other half of the periphery, to maintain the elevation of the fluid. Its inventor discovered a curious fact, in the use of the fusible alloy, (composed of bismuth eight parts, five of lead, three of tin, and one of quicksilver,) in this machine, that, like water by cooling and crystalizing, when it became solid, its dimensions increased. Unless, therefore, the metal was kept hot, or removed while in a fluid state, it burst open the pipes in which it was contained. In fact, the apparatus was burst from this cause during Onion's experiment.

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CHAPTER TWENTY-FIVE.

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ART THRIVES MOST,
WHERE COMMERCE HAS ENRICHED THE BUSY COAST,
HE CATCHES ALL IMPROVEMENTS IN HIS FLIGHT,
SPREADS FOREIGN WONDERS IN HIS COUNTRY'S SIGHT,
IMPORTS WHAT OTHERS HAVE INVENTED WELL,
AND STIRS HIS OWN TO MATCH THEM, OR EXCEL.—*Cowper.*

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WHILE one of the most brilliant applications of the steam-power had been made by its introduction to navigation, one hardly less important was contemplated by an enterprising Spaniard, who witnessing the decay of the Mexican mines, from the insufficiency of the usual methods of draining them, conceived the project of raising the water by steam-engines. These machines being unknown in Mexico, he was led, in 1811, to make a voyage to London, in order to procure the necessary information respecting them. In England, however, he met with little encouragement, in consequence of his inquiries being directed to the introduction of the atmospheric engines, which would act with a greatly impaired energy, in an atmosphere so rare as that in which the Peruvian mines are situated, added to an almost impracticability of conveying the parts which would be required for those large

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engines, over mountains inaccessible to any species of wheel-carriage.

About, says Mr. Boase, in a memoir inserted in the *Transactions of the Cornwall Geological Society*, to leave England in despair of ever being able to accomplish his grand project, and passing by a street leading from Fitzroy-square, he accidentally saw a small steam engine exposed for sale in the shop of a Mr. Roland. This was a working model which Trevithic had made of his high-pressure engine, to give a better idea of its construction and action, and which being highly finished, had found its way into the hands of its present possessor, and was exposed for sale as a cabinet curiosity. When M. Uvillé became the purchaser of this model, he felt he now had the means either of carrying forward his scheme, or of setting the fever of his mind at rest, by satisfying himself by an experiment as to the possibility of achieving his project by the medium of the steam-engine. Carrying the model to Lima, he hastened to try its power on the highest ridges of Pasco, which form the site of the mines. To his unspeakable joy, the experiment exceeded even his most sanguine wishes. He now formed an association with two opulent merchants of Lima, and, under the patronage of the Viceroy, procured the privilege of working some of the neglected mines, on the condition of giving to the state a fourth part of the produce which might be brought to the surface. " M. Uvillé again embarked for Europe, and reaching Jamaica, he took his passage for Falmouth. During the voyage, his mind was too full of the flattering prospects which his scheme inspired, not to be making frequent inquiries among his fellow passengers about mines and engines. One day while conversing with a pas-

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senger, and having expressed an anxious wish to find out if possible the author of the model, with which he had made his experiment, he was most agreeably surprised to hear Mr. Teague, the passenger, reply, 'that Mr. Trevithic was his near relative, and within a few hours after our arrival at Falmouth, I can bring you together;' it happened accordingly, and M. Uvillé resided many months at Camborne, with Captain Trevithic, receiving instructions from this highly talented individual on the construction and management of machinery. They afterwards visited together other mining districts, and in their tour they came to Soho; M. Uvillé explained to the celebrated engineers who directed that establishment, the nature of his project, and enumerated some of its difficulties; above all, the great elevation of the mines above the level of the sea, the mountainous precipices which were to be surmounted, and the absence of roads for the carriage of large masses in these extraordinary regions. But he failed in inducing these gentlemen to engage in the project.

"The enthusiasm of M. Uvillé, and the persevering enterprise of his companion, received no discouragement from this refusal. Trevithic himself engaged to provide the necessary engines; and his operations were so energetic, that in about six months afterwards, he had constructed nine beautiful machines on his own admirable model, which in September, 1814, were shipped at Portsmouth on board of a vessel proceeding to Lima, and M. Uvillé, with three Cornish miners, embarked at the same time. On their arrival at Lima, the projectors were welcomed with a royal salute, and public rejoicings; but, the local difficulties to be surmounted were so great, that it was not until the middle of

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1816, that one of the engines could be set in operation. This, the first ever seen in South America, excited intense curiosity, and the most distinguished honours were conferred on the projectors by the Vice Regal Government. The official deputation, appointed to superintend this new and extraordinary operation, in their report to the Viceroy, say, "that immense labours and boundless expense have conquered difficulties hitherto deemed insuperable, and that they had with unlimited admiration, witnessed the erection and astonishing operation of the first steam engine established in the royal mineral territory of Tauricocha, in the province of Tarma, and that they also had the felicity of having seen the drain of the first shaft in the Santa Rosa mine, in the noble district of Pasco;" "we are ambitious," they add, "of transmitting to posterity the details of an undertaking of such prodigious magnitude, from which we anticipate a torrent of silver, that shall fill surrounding nations with astonishment."

While these interesting operations were going on in Peru, Trevithic in England was vigorously engaged in providing further supplies of steam engines, and in constructing an apparatus for the Peruvian mint; but, above all, he was constructing furnaces for purifying the silver ore by fusion; a project which had become of incalculable importance to Peru, from the increasing scarcity of quicksilver.

Trevithic accompanied these engines from England, in October, 1816; his arrival at Lima in February, 1817, was announced in the Gazette, and he was immediately presented to the Viceroy, and graciously received. In the same official document, the second engine is also described as having been erected, and as being superior in power and

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beauty to the first, and that some parcels of ore of extraordinary richness had been raised from mines restored to use by the operation of these machines.

But that which the Peruvians considered to be of still greater importance, was the arrival of Don Ricardo Trevithic himself, who is described as an eminent professor of mechanics, machinery, and mineralogy, inventor and constructor of engines of the last patent, and who directed in England the execution of the machinery now at work at Pasco. "This Professor," says the Gazette, "with the assistance of workmen who accompany him, can construct as many engines as shall be wanted in Peru, without the necessity of sending to Europe for any part of these vast machines. The excellent character of Don Ricardo, and his ardent desire to promote the interests of Peru, recommend him to the highest degree of public estimation, and make us hope that his arrival in this kingdom, will form the epoch of its prosperity, through the enjoyment of its internal riches, which could not be realized without such assistance, or if the British government had not permitted the exportation from England of his machines; an object hitherto deemed unattainable, by all who know how jealous that nation is of all her superior inventions in the arts and sciences."

So much importance was attached to Don Ricardo Trevithic's personal superintendence, that the Viceroy ordered the Lord Warden of the mines to escort him with a guard of honour to the mining district, where the news of his arrival in Peru, caused the greatest rejoicings, and many of the chief men came to Lima, a distance of many days journey, to see him and welcome him. M. Uvillé in 1819, had written to his associates, that heaven

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had sent him out for the prosperity of the mines, and that the Lord Warden had proposed to erect his statue in *massy silver*.

The realities for a time kept pace, it would appear, with the promises;—Don Ricardo's labours were successful, and the coining machinery increased sixfold.

The year before Trevithic left England he made a considerable improvement on his engine, by forming the piston so that a ring of water should run all round it, and render the whole air-tight; as in practice he found, that a very moderate degree of tightness in the packing, produces this effect; and he revived the idea of giving motion to steam waggons, by means of the re-action of the steam made to spout against the atmosphere; and suggested the use of a spiral-wheel, revolving at the stern of a vessel as a means to propel it forward, preferable to paddle wheels at each side.

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CHAPTER TWENTY-SIX.

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"RESPECT AND PITY ARE DUE TO THE CHARACTER OF A PROJECTOR—RESPECT, BECAUSE SOCIETY OWES TO IT MANY OBLIGATIONS, AND MUCH OF THE PROGRESS OF THE USEFUL ARTS MUST BE ASCRIBED TO ITS EXISTENCE; BUT PITY, BECAUSE IT IS UNFRIENDLY TO THE INTERESTS OF THE INDIVIDUAL, AND GENERALLY PLUNGES HIM FROM AFFLUENCE INTO RUIN."—*Evans.*

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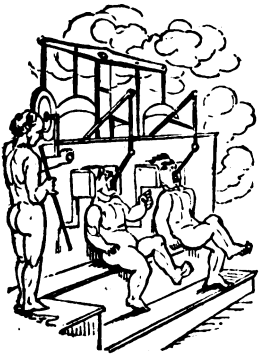

THE apparatus which Symington had nearly perfected, and with which he made his successful experiment, had been for years laid up to rot in a corner of the canal on which it was first exhibited; and chagrin and disappointment were perpetrating on the mind and fortune of its excellent inventor a havoc similar to that which the elements were spreading over his beautiful mechanism. He could now only be a nerveless spectator of the triumph which another man was reaping from the same invention, in a shape hardly more perfect than his own; and which, probably, derived some of its practical merit from an inspection of his neglected steam-boat.

Henry Bell, a self-taught engineer, to whom, as we have seen, Fulton had written regarding Miller's experiments on the Dalswinton Loch, being placed in a more favourable situation than Symington, on receiving the letter from Fulton, was led, he says, to think of the absurdity of

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sending his opinions on these matters to other countries, and not putting them in practice himself in his own; and from these considerations, he says, "I was roused to set on foot a steam-boat, for which I had made a number of different models before I was satisfied. When I was convinced they would answer the end, I contracted with a ship-builder in Greenock, to build me a steam vessel according to my plans, with a forty-feet keel, and a ten and a half-feet beam, which I fitted up with a small portable engine having the power of three horses, and paddles, and called her the COMET, because she was built and finished the same year that a comet appeared in the north-west of Scotland. This vessel is the first steam-boat (built in Europe) that answered the end, and is still upon the best and simplest method of any of them *."

* From a misapprehension of an expression in Mr. Bell's examination, the Committee of the House of Commons, in their Fifth Report on Steam-Boats, state, "that the whole merit of constructing steam-boats is due to the natives of Great Britain. Mr. Henry Bell, of Glasgow, gave the first model of them to Mr. Fulton, *and went over to America to assist him in establishing them.*" This account, we fear, has operated to the prejudice of an ingenious and deserving man. Mr. Bell's claims to public reward need no bolstered statements or pretensions, and we have reason to believe that he has himself disclaimed both the assumed fact and its inference. Mr. James Cleland, a warm and judicious friend of Mr. Bell, places his merit in its proper position when he says, "that, without assuming for Bell the merit of instructing Fulton, or believing that he ever crossed the Atlantic, as has been erroneously stated elsewhere, there cannot be a doubt that he was the first person in Europe who successfully impelled vessels by steam." Cleland mentions another circumstance, which reflects great honour on some of his townsmen. "In 1813, after Mr. Bell had expended a larger sum of money than he could well afford, on experiments, (many of which I witnessed,) a number of his fellow-citizens *requested him to allow them to defray part of his outlay.* Among those who were foremost

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At the same moment, that Mr. Bell was exerting himself on the Clyde, a Mr. Dawson was also making some experiments in Ireland, and according to his own statement, had, in 1811, built an experimental steam-boat of fifty tons burden, and worked her by a small high pressure steam-engine; by a most extraordinary coincidence, he also named his vessel the Comet. "In 1813 the same individual established a steam-packet on the Thames, to ply between Gravesend and London *, which was the first that did so for public accommodation, although a Mr. Lawrence of Bristol, who introduced a steam-boat on the Severn, soon after the successful operations on the Clyde, had her carried to London to ply on the Thames; but from the opposition of the watermen to the innovation, he was in the end obliged to take her to her first station†."

in this act of justice were, Mr. Kirkman Finlay, then Member of Parliament for Glasgow; Mr. Archibald Campbell, the present Member (1825); Mr. Henry Monteith, now Member for Lanark; and Mr. John Buchanan, Member for Dumbartonshire."—CLELAND's *Hist. Account*, p. 58.

* This vessel was afterwards sent to Spain, and plied between Seville and San Lucar.

† The opposition of the watermen to the introduction of steam-boats, especially to those which navigated above the bridges, was made on the ground that they had, by charter, an exclusive right to carry passengers on the Thames within a certain jurisdiction; and also from an apprehension of injury to their individual means of obtaining a livelihood. In one or two instances they succeeded in deterring individuals from sailing steam-boats; but the attempt at monopoly ultimately was "foiled, by the extensive legal knowledge of Mr. Tyrrell, the City Remembrancer, one of the most early and liberal friends of the Richmond steam-yachts; and experience has proved that, instead of injuring, the watermen have been greatly benefited by the surprising number of persons they have to put on board and to land, and who, but for this enticing mode of carriage, would not have required boats."—DODD *on Steam Boats*, p. 233.

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Notwithstanding the meritorious nature of his enterprise, the first year Bell's speculation turned out to be a losing one; "for so great," says he, "was the prejudice against steam-boat navigation, by the hue and cry raised by the fly boat and coach proprietors, that for the first six months very few would venture their precious lives in her. But in the course of the winter of 1812, as she had plied all the year, she began to gain credit; as passengers were carried twenty-four miles as quick as by the coaches, and at a third of the expense, besides being warm and comfortable. But even after all, I was a great loser that year. In the second year, I made her a jaunting boat all over the coasts of England, Ireland and Scotland, to show the public the advantage of steam-boat navigation over the other mode of sailing;" and with a pardonable vanity, he exults on "having done (in Great Britain) what no king, prince, admiral or general could do—made vessels go against both wind and tide, which had not before been accomplished in this country, so as to make them of any use to the public."

Previously to the voyages of the Comet, the average number of travellers between Greenock and Glasgow was eighty up, and eighty down; in four years afterwards it was not unusual for five or six hundred passengers daily to enjoy the healthful amusement of a water excursion, and the enchanting beauties of the Clyde.

The second vessel constructed on the Clyde, was on the same model as the Comet, but she was a third longer, and her engine had upwards of three times the power. But the Elizabeth differed from the Comet, in being a profitable concern to her proprietor (Mr. Hutchison, a brewer,) from the first day she plied as a passage-boat between

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Glasgow and Greenock. These two vessels having encountered all the vicissitudes of wind and weather, incidental to a navigation of twenty-seven miles on a tide-river, in some parts four miles wide, inspired such deserved confidence in this kind of navigation, that other individuals were led to the erection of larger and more commodious vessels to ply on the same route.

The third steam-boat on the Clyde was intended to be an improvement on the common construction; Mr. Robertson Buchanan*, an en-

* ROBERTSON BUCHANAN was born at Glasgow in 1769; his father was a cadet of an ancient family, which had been long seated in that part of the country; and his mother was a daughter of Mr. A. Robertson, who held the office of Chamberlain of the city, and was one of its most influential inhabitants. His grand uncle, Mr. Neil Buchanan, represented the borough in parliament. His father, who traded as a merchant to America, during the war which ended in the independence of the Colonies, having lost the whole of his property, upon receiving some calamitous tidings, in a paroxysm of despair felt life to be insupportable. His family was left totally unprovided for. *George*, his eldest son, afterwards settled in Jamaica, where he rose to affluence, and returned to England in 1817. *Robertson*, at the death of his father, being in his sixteenth year, having given indications of a taste for drawing and mechanics, was placed for a short period with a carpenter, in order to give him a practical knowledge of that branch of construction, and he also subsequently worked as a millwright, with the view of emigrating to the West Indies as an engineer. Leaving Glasgow "for improvement," he resided, for about a year, near Dartford in Kent; after which he returned to his native town and commenced business on his own account. This he was tempted to relinquish for the direction of the great cotton spinning establishment in the Isle of Bute, in which unfortunately he accepted of a share as partner. In this unprosperous concern, he lost his health as well as his proportion of the pecuniary sacrifice.

In 1796, during his residence in Bute, he had taken out a patent for *a pump* which was not liable to be choked, and at leaving the Island in 1801, he went to London for the purpose of bringing his invention into notice. Government

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gineer, well known as a practical mechanic of the first order, made the paddles of the water-wheels enter the water perpendicularly to its surface, and

afforded him facilities for making experiments with his apparatus on board a ship of war, and he was personally noticed by George III. His hopes, which had been much excited, in consequence of the high quarters from which he was encouraged to proceed, were not to be realized; the pump failed in lifting water from the depth which was required before it could become useful on shipboard. Nearly two thousand pounds had been expended on the invention, when its author reluctantly left it to its fate.

At his return to Glasgow, he engaged a second time in the cotton manufacture, and was the first who succeeded in introducing *cotton-thread*, as a substitute generally for that made from flax, which hitherto had been exclusively used by sempstresses. This was known as *Adelphi* sewing cotton, from the name of his manufactory, (in which he was associated with Mr. Robert Thomson,) and the machine by which the thread was wound into elegant balls was, it is said, of his invention. When in London, he had formed friendships with Professor Pictet and Count Rumford; and his attention being directed to the count's method of warming buildings, he gave a good account in a small pamphlet, printed at Glasgow in 1807, of his success in heating the Adelphi works by steam. Ill health again compelled him to abandon an employment which he found to be pernicious; and resuming his early and more congenial pursuits he commenced his future profession of a *consulting-engineer*. After this he was fully employed in giving designs and instructions for the erection of machinery: that which he planned for some large bleacheries brought him much reputation. He superintended the erection of the works on Cranstonhill, for supplying the city of Glasgow with water; he made a survey of a rail road between Sanquhar and Dumfries. His report on this project is an exception to such productions in general, in its freedom from exaggeration; it is brief, clear, comprehensive, and above all, candid. The bridges he erected at Inchinan in the county of Renfrew, are unique in their plan. The rivers Griff Cart, and White Cart, unite into one stream before they empty themselves into the Clyde, dividing the highway between Glasgow and Greenock. On the tongue of land at the junction of their currents is a road to Paisley. Buchanan threw a bridge across each river at right angles to their respective streams, and connecting their re-entering angles

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rise from it nearly in the same manner, thus imitating what was considered to be the advantageous part of the action of a common oar. Buchanan was associated with two other wealthy citizens, both of whom had some experience in machinery; their operations excited much local interest, and their boat was called that of the "Three Wise Men." The mechanism was an ingenious one, but

by a revetment wall, he made the road to Paisly branch off opposite their junction; a bird's-eye view, therefore, shows three roads meeting each other at an angle of 120 degrees. They are probably the most ornamental public structures of the kind in the kingdom. Their architectural details are in a good style, which may be accounted for, from Buchanan's early cultivation of a fine natural taste, and which also pervaded—strongly pervaded—his conduct in his general intercourse with society. His habits were simple, his address frank and unaffected, and in his various social relations his life was an example of every Christian virtue, without the shadow of a pretension to the possession of any. As a relative and a friend, he was tender, conciliating, and trusty; and his memory is still cherished with reverence and affection, by those with whom he was connected as a master. In his lifetime they regarded him with attachment for his amiable disposition, and the disinterested, unwearied, and benevolent zeal he showed to promote their happiness and welfare. As an author, his works have been very favourably received by the public—they are valued by practical men for the great mass of useful facts which forms their staple, and for the soundness of the practical deductions he draws from them. His first work was *Observations on Heating Buildings by Steam:* this he enlarged and republished in 1810, under the title of an "Essay on the Management of Heat and Economy of Fuel." An *Essay on the Teeth of Wheels.*—Six *Essays on Millwork* were printed in 1814; and a *Treatise on Steam-Boats* in 1816; some of his papers were inserted in the earlier volumes of the "Repertory of Arts," and his account of the articles Cotton Manufacture, and Life of Sir Richard Arkwright, in "Brewster's Encyclopedia."

He died in July 1816, at Creech St. Michael, near Taunton, to which place he had gone, a few weeks before, on a visit to his uncle, Doctor Innes, to try the effect of a change of air as the last remedy, hope pointed out to his friends, for arresting the rapid progress of a fatal disorder.

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the friction from the eccentric movement, which produced the parallelism of the paddles, being enormous, the scheme was abandoned.

Fulton having succeeded in establishing the validity of the grant made to Livingstone and himself by the Legislature of New York, of the sole right to navigate the waters of the State by wheel steam-boats, against numerous successive encroachments *, was assiduous in introducing his vessels on these waters; and about this time he was actively employed in the construction of a floating battery, to be moved by wheels and a steam-engine, the keels of which were laid in June, 1814: she was about one hundred and fifty-six feet long, and fifty-six feet broad; the cylinder was four feet in diameter; and the piston made a stroke of five feet; the water-wheel was sixteen feet in diameter; and the paddles dipped four feet into the water. Her burden was about two thousand five hundred tons.

"This steam-frigate was a structure resting upon two boats and keels, separate from end to end by a canal fifteen feet wide, and sixty feet long: one boat contained the caldrons, made of copper, to

* One of the most notable of these opposition schemes, which were started on the Hudson River to annoy Fulton, was a vessel propelled by a *pendulum!* "which, according to the calculations of some ingenious gentlemen, would give a greater power than steam; but when the boat came to be put into the water, they found that their wheels, which were turned with great facility and velocity, while their vessel was on the stocks, could not be made to perform their functions without the application of a great power to the pendulum; the projectors were utterly at a loss to account for so extraordinary a phenomenon, and could not conceive why the wheels, which had moved so much to their satifaction, when they were resisted by the air only, should require so much force when they turned in the water, and were to drag the weight of the vessel!!"—*Colden.*

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prepare her steam; the vast cylinder of iron, with its piston levers and wheels, occupied a part of the other boat; the great water wheel revolved in the space between them *; the main, or gun, deck supported her armament, and was protected by a bulwark, four feet ten inches thick, and of solid timber; this was pierced by thirty port-holes, to enable as many thirty-two pounders to fire red hot balls; her upper, or spar deck, on which several thousand men might parade, was plain, and surrounded with a bulwark, and she could be propelled by her machinery alone; but to enable her to take advantage of the wind, she was furnished with two stout masts to support latteen sails, and bowsprits for jibs, with the necessary rigging, and four rudders, one at each end. Fulton also intended to have fitted an apparatus for discharging an immense column of water upon the decks, and through the port-holes of an enemy, and thereby deluge her armament and ammunition; and also

* "Mr. Richard Wright, late of Yarmouth, constructed a vessel called the Eagle, nearly on this plan:—she was uncommonly slow; this was erroneously attributed to want of power in the engine, and another engine of much greater power was placed on board; yet this but little increased her speed, which appeared about three miles and a half an hour, whereas the same engine, with paddles over the sides properly situated, would undoubtedly have produced nearly double that rate of going. A person, named Greathead, tried nearly a similar experiment, at a vast expense, and totally failed."—Dodd, p. 225.

"In 1819, three scientific gentlemen of Glasgow conceived the idea of propelling vessels without paddles, the scheme was to discharge water from behind the vessel with great velocity, from pipes placed under the surface, by which she was to be propelled. After an expensive preparation an experiment was made on the Clyde in November, when it was found that the propelling power was not sufficient to move a vessel against the tide—the scheme was therefore abandoned."—Clelland, p. 50.

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to suspend from each bow two two-hundred pound columbiads, to discharge a ball of that size below the antagonist's water line."

In July, 1815, this colossal vessel made a voyage of fifty-three miles to the ocean and back, in about eight hours and twenty minutes; and in her third voyage, when she had nearly the whole of her armament on board, and her draft of water about eleven feet, she made another voyage to the ocean, solely impelled by her machinery, and moved with a speed equal to five miles and a half an hour. "During this voyage she changed her course, by inverting the motion of her wheels, without the necessity of putting about. She was perfectly obedient to her double helm, and performed some beautiful manœuvres round a national frigate; fired several salutes, in which it was observed the explosion of the powder produced very little concussion, and the machinery was not affected by it in the slightest degree." But Fulton was not destined to enjoy the satisfaction of witnessing the success of this magnificent experiment; he was seized with inflammation, brought on by exposure to cold, during one of his visits to inspect the progress of the workmen, which terminated fatally in February, 1815 *.

* "It was not known that Mr. Fulton's illness was dangerous till a very short time before his death, which was unexpected by his friends, and still more so by the community. As soon as it was known, all means were taken to testify publicly the universal regret at his loss, and respect for his memory. The newspapers that announced the event had those marks of mourning which are usual in our country when they notice the death of public characters. The corporation of our city, (New York,) the different literary institutions, and other societies, assembled, and expressed their estimations of his worth, and regret at his loss; they also determined to attend his funeral, and that the members should wear badges of mourning for a certain time; the Legislature,

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The boats which had been established on the American rivers, and on the Clyde, had occasionally experienced some heavy swellings of the

then in Session at Albany, expressed their participation in the general sentiment, by resolving that the members of both Houses should wear mourning for some weeks.

"This is the only instance, we believe, of such public testimonials of regret, esteem, and respect, being offered on the death of a private citizen, who never held any office, and was only distinguished by his virtues, his genius, and the employment of his talents.

"His funeral was attended by all the officers of the national and state governments then in the city; by the magistracy, common council, a number of societies, and a greater number of citizens, than have been collected on any similar occasion; and during the progress of the procession minute guns were fired from the steam-frigate and West battery; and shortly afterwards a principal street, which was opened by the corporation, was called by his name.

"Mr. Fulton, in contributing his proportion to the magnificent boats on the Hudson, each of which cost from forty to sixty, and the last one which was built, upwards of a hundred thousand dollars, expended immense sums of money. The experiments he was always making required very large disbursements; and the law suits in which he was incessantly engaged, from the moment his boats were seen in successful operation, were very expensive. Owing to these, among some other circumstances, although he lived without ostentation or extravagance, he left his estate most excessively involved; and it is certain, that unless some stability be given to the exclusive grants from the State, the only patrimony of his children will be that load of debt which their parent contracted in those pursuits which ought to command the gratitude, as they do the admiration, of mankind."—COLDEN, p. 257.

"Mr. Fulton," says the same warm friend and admirer, "was about six feet high; his person was slender, but well proportioned; nature had made him a gentleman, and bestowed upon him ease and gracefulness; he had too much good sense for the least affectation, and a modest confidence in his own worth and talents gave him an unembarrassed deportment in all companies: his features were strong, and of a manly beauty; he had large dark eyes, and a projecting brow, expressive of intelligence and thought; his temper was mild, and his disposition lively; he was fond of society,

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sea; but the impression among nautical men was against the notion, that they could ever be depended upon to remain at sea, in weather which could be braved by a common sailing vessel.

The point was decided by Mr. George Dodd, "a very resolute young man, who went to Glasgow expressly for the purpose of fitting a steamboat for sea, and bringing it to London. He had served as an officer in the English navy, and he afterwards distinguished himself as a civil engineer, an architect, and even a topographer*. His

which he always enlivened by cheerful, cordial manners, and instructed or pleased by his sensible conversation: he expressed himself with energy, fluency, and correctness; and as he owed more to his own experience and reflections than to books, his sentiments were often interesting from their originality. He was decidedly a republican.

"In all his domestic and social relations he was zealous, kind, generous, liberal, and affectionate; he knew of no use for money, but as it was subservient to charity, hospitality, and the sciences; but what was most conspicuous in his character was his calm constancy, his industry, and that indefatigable patience and perseverance which always enabled him to overcome difficulties."—COLDEN, p. 258.

* RALPH DODD was a portrait-painter before he became an engineer—for the last twenty-five years of his life he was a manufacturer, mostly of steam-engines, and was known to the public as a man of talent and ingenuity; he had some patents, one or two of them connected with the construction of the boilers of steam-engines. He died at Cheltenham in 1822, in very indigent circumstances. His wife, to whom he had been married for forty-six years, and then in her seventieth year, having outlived all ability to help herself, could look forward only to the cheerless and inhospitable shelter of a workhouse, as the last resource of her calamity,—the resting-place of her despair; when the forlorn and destitute condition of the aged widow was made known to one of those societies whose mercy, be the circle of human misery ever so extended, sweeps a yet wider circle and embraces it—its bounty softened the pillow of her sickness and smoothed her bed of death. Four children survived her: *Robert Baradell Dodd*, the eldest, practised as an engineer, and, occasionally, as a portrait-painter at Newcastle. *Thomas Dodd* served

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vessel was about ninety feet long, and fourteen and a half feet broad, had a burden of about seventy-five tons; the engine was calculated, to

with distinction as a commissary under the Duke of Wellington. *Fanny Dodd*, whose present situation makes her indeed an object deserving the merciful assistance of the benevolent—the misfortunes of her family and her personal privations, unhappy gentlewoman! have threatened the total wreck of her mind. *George Dodd*, the third son, is the individual mentioned in the text. He was the designer and author of Waterloo Bridge, and held for a time a lucrative appointment as its engineer which, from some unexplained circumstance, to the surprise of his friends he resigned. His nautical skill was displayed to advantage at the first introduction of steam-passage-boats on the Thames, and his practice in altering and improving several of these vessels was directed by good tact and judgment; he introduced the mechanism of the lowering chimney, but his little success as a co-proprietor in some boats did not correspond with his exertions to deserve better fortune. In the excitement produced by the use of wine, he endeavoured to seek relief from the depression of mind occasioned by a waning fortune; but this only plunged him deeper into embarrassments and accelerated their fearful termination. The close of his life was awful. He had hired lodgings at the house of a person to whom he was unknown; but returning at a very late hour to take possession of them, in a state of ebriety, the inhuman landlord thrust the wretched man into the street, where he was found lying almost in a state of insensibility by the patrol, and carried to Giltspur Street Compter. Next morning he was taken before the Lord Mayor as a vagrant. "His Lordship, who knew him in the days of his prosperity, recognised him among the crowd of paupers who appeared craving relief, and asked some kind questions, which, however, poor Dodd seemed unwilling to answer. He indeed appeared as if "sharp misery had worn him to the bone," and he evidently laboured under an infirmity of intellect. All he asked was liberty to stay at the Compter until he could make arrangements for his removal—his request was cheerfully complied with. But the unfortunate man, suspecting that it was intended to give him poison, refused to put his lips to any thing that would do him good; he lingered for eight days when he expired."

He was the reputed projector of the Gravesend Tunnel, and had very lately taken out a patent for an ingenious machine

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have a power of fourteen horses, and the wheels were nine feet in diameter. She was rigged with a square sail on the chimney-mast, a bowsprit sail, and another on the mainmast. The crew consisted of a mate, four seamen of the first order, an engineer, a furnaceman, and a ship's boy. This was the first vessel of the kind that any one had ever dared to venture in on the tempestuous sea that terminates St. George's Channel in doubling Cape Lizard.

"The commencement of his voyage was not happy. The weather was very bad, and in the narrow channel which separates Scotland from Ireland, the sea is sometimes terrible, by the rencontre of the ebb tide with the heavy swell that comes from the Atlantic Ocean. He was forced to seek shelter in Loch Ryan, owing to the ignorance and presumption of the pilot, who, after the captain had retired to rest, altered the course he had been ordered to steer during the night, to gain the coast of Ireland by morning. At break of day the crew disturbed the captain to warn him of his danger: he immediately discovered that the wind had freshened to a heavy gale, attended with a high and irregular sea; and that instead of his vessel being on the coast of Ireland, she was within half a league of a lee rock-bound shore, two miles to the north of Port Patrick, Scotland. It blew too violent to attempt beating off this coast by sails and steam united; he, therefore, struck the little sail that was standing, and the mainmast

for extinguishing fires on board ship, which it appeared, from letters found in his pocket after his death, had been introduced into some vessels of war: the contrivance is described, and a figure of it given, in HEBERT'S *Register of Inventions*, vol. iii. p. 294. He was the author of a *Treatise on Steam-Boats*, published in 1818.

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constructed to lower, and depending entirely on the power of his engine, laid the vessel's head directly to windward, and ordered the log to be kept constantly going, which quickly ascertained, that the vessel was clearing the coast, and going direct in the wind's eye, at the rate of three knots and a half per hour. When he made a sufficient offing he bore away for Loch Ryan, and soon came up with a brig in distress, running for the same place, having carried away her main-topmast during the gale: a second attempt succeeded, and gained the coast of Ireland. No other power than that of steam would have impelled the vessel against that wind, and saved it from destruction.

"On leaving Dublin," continues Weld, "we left far behind us all the vessels that set out with the same tide, and next morning, as we passed Wexford, the thick smoke which issued from the mast, was observed from the heights near that city, and it was concluded that the vessel was on fire. At the instant all the pilots put to sea to fly to our assistance, and at the arrival of the first who reached us, it is impossible to describe the attitude of surprise, mingled with disappointment, which they evinced at beholding us in very good condition, and which frustrated their claim for salvage. While we were crossing St. George's Channel one of the paddle blades, which was put out of order, was cut away by a steel chisel. Some hours afterwards, a similar accident happening to the other wheel, it was remedied in the same way. It was not perceivable that one paddle-blade less in each wheel produced any sensible effect in the progress of the vessel.

"At the entrance of the channel into St. Bridge's Bay, from the tide descending Ramsey Channel, in a straight and boisterous current, and

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the tide rising on the other side in an opposite direction, the waves were very high, and dashed against each other in all directions; and their turbulence, when we came into contact with them, was truly alarming: we often found ourselves so low between two waves that they hid the sight of the coast from us, although it is very high; but the vessel made way over all these obstacles in the finest style. A small fleet of merchantmen quitted the pass and endeavoured to follow us, but in the passage of the bay alone we outrun them all hull down.

"On the other side of St. Bridge's Bay the pilot warned us of the danger there was in endeavouring to pass a strait passage, called Jack Sound, except at high tide, and with a good wind. 'There were,' he said, 'a most rapid tide, and whirlpools, which would seize the ship and carry it on rocks level with the water's edge. Captain Dodd, who knew the power of his wheels, insisted on going forward, which would save us, probably, another night at sea. The pilot re-urged his remonstrances, and trembled with fear, but we crossed all these whirlpools freely, and without appearance of danger. Nothing, however, was more frightful than the appearance of these rocks, and the sea strikes against them in hollow waves that resound on all sides. Our situation there at the beginning of night, in a vessel that had no other resource than the wind to get out, would have been very perilous, but our powerful and indefatigable wheels soon extricated us out of this danger, and brought us safe and sound into Milford Road.

"In approaching that place we met the king's packet-boat, with all sails spread to the wind, and had passed it about a quarter of a mile when the

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captain bethought him to transmit some letters by it: we put about and reached it in a few minutes, and went round it, notwithstanding it continued under weigh; and after delivering our communications to the captain, we went round it a second time and regained Milford Point.

"When anchored in the port of Hayle, a vessel which contained eleven persons, with a party of pleasure, just at the mouth of the river, had been carried away by the tide and wind, and hurried on the rocks before any person perceived the danger. Captain Dodd discovered the vessel and its perilous situation: scarcely had he time to declare it when the calamity was at its height. This brave man, confident in his four rowers, boldly advanced amongst these rocks and breakers, and at the imminent risk of their lives succeeded in snatching from the waves four of the wretched individuals who still had signs of life. But notwithstanding the indefatigable cares of Captain Dodd, and of those persons to whom he dictated the means prescribed by the Humane Society, only two of them survived this sad event.

"In doubling the Cape of Cornwall, the first of those two great promontories which terminate England on the west, a frightful swell met us, with all the weight of the Atlantic; whilst the tide, which running down St. George's Channel, met those waves and raised them to a height which it appeared impossible to overcome, and equally dangerous to have in the rear if there were occasion to put about. The vessel appeared to suffer, and the repeated dashings against the case of the wheels alarmed the pilot, who heard them for the first time; night approached without any port offering itself to us. In this state of things Captain Dodd observed that the vessel

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sailed better before the waves than in any other direction; he, therefore, made a long tack, close hauled, so that we might get out of the latitude where the swell struggled against the tide. We spread some sails, which always contributed to the equilibrium of the vessel, and at the end of some hours we had doubled the Land's-End, when we found ourselves in a tranquil sea. After this there was nothing more in the voyage either laborious or remarkable; we were then at the entrance of the British Channel, which is said to be always more calm than the Irish Sea. The sun shone on us, the sea sparkled with its beams, and the coast unfolded all its beauties—we beheld its woods, its villages, its rich cultivation." *

This interesting voyage, 758 nautic miles, was run in about 122 hours.

* Account of a Passage to London in a Steam-boat, by Isaac Weld, Esq., *Journal des Mines*, for September, 1815;—extracted by Dodd in his *Treatise on Steam-Boats*.

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CHAPTER TWENTY-SEVEN.

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" NOTHING IS HERE FOR TEARS, NOTHING TO WAIL,
OR KNOCK THE BREAST; NO WEAKNESS, NO CONTEMPT,
DISPRAISE OR BLAME; NOTHING BUT WELL AND FAIR,
AND WHAT MAY QUIET US IN DEATH SO NOBLE."

Milton.

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THE acquisition of literary knowledge, in which Watt engaged with all the ardour of a student, filled up the leisure of his retirement; and it was during this period he acquired much of that store of information for which he was subsequently considered to be almost as remarkable, as he was for the powers of his invention. Few individuals of his class possessed "so much, and such varied, and exact information, had read so much, or remembered what he read so accurately and so well. His information was general. That he should have been intimately and extensively skilled in chemistry and the arts, and in most of the branches of physical science, might, perhaps, have been conjectured; but it could not have been inferred from his usual occupations, that he was curiously learned in many branches of antiquity, metaphysics, medicine, and etymology; and perfectly at home in all the

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details of architecture, music, and law. He was well acquainted too with several of the modern languages, and familiar with their most recent literature. Nor was it at all extraordinary to hear the great mechanician and engineer detailing and expounding, for hours together, the metaphysical theories of the German logicians, or criticising the measures or the matter of the German poets.

"He still took a lively interest in those projects which were afloat in the mechanical world, and kept up an intercourse with his former associates;" and occasionally accepted of invitations to give his opinion and assistance as an engineer. But this he did but rarely, for his pecuniary ambition being satisfied, he valued his ease, as leaving him perfectly independent in the disposal of his time.

It has also been noticed by some who were ignorant of the peculiarities of his character, to be a circumstance somewhat extraordinary, that this long period of philosophic retirement was undistinguished by a single invention from his hand. Nay, even that although his whole life had been spent among mechanics, and he was acknowledged to possess a superlatively fertile imagination, he is known as an inventor solely for his labours on the single mechanism of the steam-engine. For his method of copying writings, the pneumatic apparatus, designed for Dr. Beddoes, and the pipe for conveying water across the Clyde, which accommodated itself to the bend of the river, are but trifles, even when compared with the devices of hundreds of his cotemporaries. This anomaly is the effect of a very striking peculiarity in the constitution of Watt's mind,—his apparently perfect indifference, or rather total insensibility to personal distinction, or to the fame

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of an inventor. He looked at his projects only as a source of profit; provided he had this, he cared not who had the merit of being their author; and when he saw emolument could not be drawn from them, numerous inventions were thrown aside, and allowed to sink into oblivion—to perpetuate them by a description never entered into his imagination; and even those improvements on the steam-engine, on which his fortune, and that of his family, depended, were about as unknown to the public as some of his neglected contrivances. He not only had never imparted any account of these inventions himself, but he even shrunk from the task of enabling his friends to give them, in order to repel the insinuations which were thrown profusely upon him, for the purpose of invalidating his patent; and when Bolton appealed to the law, Watt was uneasy under the publicity which the proceeding gave to his operations—to the homage which was paid to his genius. At length, when he was urged to revise a sketch given by Dr. Robison *, he contented himself with adding a few notes to his friend's work, remarkable for their candour, and for their utter freedom from all affectation and pretension. Indeed, his own opinion of his own inventions was quite opposite to that of his friends and the public; he valued them lightly, probably as having cost him but little effort to produce them; and those contrivances, which had carried his name to every corner of the world, he considered to be so obvious, that they must have occurred to thousands of others before his time, and that he was

* *Elements of Mechanical Philosophy*, vol. ii. art. Steam-Engine.

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more fortunate only than they, from being the first who had put the thought to the test of experiment.

"His knowledge was, however, of a useful kind, and, unlike some of his cotemporaries, he valued it for its practical tendency, not for the manner in which it was, or could be imparted; he had no relish for what was called abstruse mechanical discussion, and on theoretic deduction he never placed any dependence. In this he resembled Smeaton; every thing was done by a sort of feeling, or tact, as if the knowledge had been born with him. In his opinions he seldom went either before or beyond the direct inference which could be drawn from an experiment; but so great was his sagacity, that few bearings of an experiment were omitted or overlooked. Not the least extraordinary part of his character was his indifference to the study of mechanics as a science, or even as an art; and few men, who had read so much on general topics, ever read less on this, the knowledge of which, of all others, we might consider to have been essential to the proper development of his conceptions; and he never was, at any period of his life, a scientific man, in the present absurd acceptation of the term: it has been said, that he never resolved an algebraic equation in his life. Like Ferguson, he got at the truth by geometrical methods; and at one period of his life it was his favourite amusement to represent, by geometrical figures, various tables which he had occasion to consult in directing the proportions of his engines. These, it is said, gave his pupil, Playfair, the idea of his ingenious system of linear arithmetic *."

* STUART'S *Des. Hist. of the Steam Engine*, p. 190.

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Playfair observes* that he was ignorant whether "he ever was a dexterous operative mechanic," but he certainly never attempted to assist in

* WILLIAM PLAYFAIR was the third son of the Rev. James Playfair of Benvie in Forfarshire, where he was born in 1759; The death of his father happening while he was young, his education and maintenance chiefly devolved on *John* his elder brother, the late distinguished professor of natural philosophy in the University of Edinburgh.

William, having shown an early taste for the mechanical arts, was apprenticed, for a short period, to Andrew Meikle, the inventor of the threshing machine; here he had the late Mr. Rennie, the engineer, as his shopmate. Playfair, having acquired considerable facility in mechanical drawing, "with that instinctive partiality for the south, which does no dishonour to Scotchmen, but which may have been of advantage to both countries," went to Birmingham in 1780, as a draughtsman to Mr. James Watt, and remained with him for several years. From this intimacy is derived almost all that is known of the early habits of the great improver of the steam-engine.

At leaving Soho, Playfair aspired to literary distinction, and in an evil hour essayed to become a political advocate. At first, however, the writing mania divided his attention with mechanics, for he found time to carry into execution a method of making what he called El Dorado window-sashes and doors, of a metal composed of copper, zinc, and iron. He also invented a machine for forming the ornamental fret work on articles of silver, which had hitherto been done by hand, and opened a shop for the sale of plate of this manufacture: by the same engine he fabricated coach ornaments, buckles, and horse-shoes; of the latter he could produce ten in a minute.

This adventure, which wanted only a little perseverance and attention to have made it become a permanently lucrative one, did not make returns fast enough to satisfy Playfair's restless activity. He went to Paris, for the purpose of introducing a new rolling-mill, and Cort's improvement in manufacturing iron; and, as an encouragement for him to proceed in the erection of his manufactory, he received a grant of a piece of land from the court. The unsettled state of French affairs was unfavourable to this project. Joel Barlow had been dispatched to Paris, as agent for a company which had purchased a tract of nearly three millions of acres of land on the river Sioto, which empties itself into the Ohio. Experi-

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making models or putting any of his own plans into execution after he came to England, whatever he might have done at an earlier period of his life.

encing great difficulty in the disposal of the lands, he induced Playfair to undertake the business. In two months he sold fifty thousand acres. This, though not a very flourishing, is yet an improving settlement; and Playfair, in his old age, consoled himself, that when much of what he had written on politics was forgotten, his name would be remembered, from his connection with the Sioto colony. The great scarcity of silver coin at Paris making paper money of every kind nearly useless, Playfair's next speculation was a good one. He opened a bank for the issue, at a small premium, of *his own notes*, payable on demand, *for quarter francs, half francs*, and *francs*. This manufacture was every thing he could wish for on the score both of extent and profit; for *his notes* were demanded in thousands and tens of thousands, and they were returned occasionally only in fives and tens. Playfair, however, having expressed himself with incautious freedom regarding some measures of the French government, *his bank* was regarded as *fair prey*. From a friend at headquarters he received, in the afternoon, intelligence of what was in contemplation, in time to remove a large sum of the national notes, for which he had exchanged his own. Next morning a small party of gens-d'armes marched into his office, accompanied by an officer of the police, who took a list of the stock, and, sealing it up, he left a couple of soldiers to look after the premises. The banker's body was also anxiously sought for, to be described in the inventory; but Playfair was on his way to Holland, which he reached in safety. Happening to be at Frankfort on the Maine, when a member of the Parliament of Bourdeaux arrived at the same inn, and described a telegraph which had been erected on the mountain of Belville, Playfair instantly began a model, which, on the third day after, he sent to the Duke of York, and thus the plan and an alphabet of this apparatus first came to England.

At his return to London in conjunction with Mr. Hartsinck, of the celebrated house of the Hopes at Amsterdam, and the Rev. Mr. Hutchinson, he established what he called a Security Bank, for advancing money or transferable notes, on valuable property, but of a nature which prevented its being easily brought to market. In this every thing depended on a perfect knowledge of property of all kinds, and the exercise of the most *rigid caution*; these were found wanting,

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He employed most of his time in drawing and writing letters, but very little of it in superintending the operations that were going on. This

and bankruptcy followed. The affairs of the company were thrown into Chancery; and it is said they remain there still —all the partners have gone to their long account.

After this wreck, Playfair became an author by profession; and his future life was a chequered one, even for that of a man of letters. He wrote on a variety of topics, but politics and national-economics were his favourite subjects, and almost every popular question of the day elicited a pamphlet from his hand. Many of these were eminently successful. His greatest work, and the one too for which (if we except his skill in linear tables, which he turned to good account in his charts of domestic chronologies) he was the least fitted, was his *Family Antiquities*, in nine large quarto volumes; this was published at forty-five guineas. But his *Statistical Breviary and Atlas* are, perhaps, the works which best exhibit his ingenuity; these introduced him to many high political characters, and, among others, to the late Marquis of Lansdowne. He added *Notes to Smith's Wealth of Nations*, and was the author of *Oddy's European Commerce*. *France as it is: not Lady Morgan's France*, was a later publication. But that which he spoke of with the greatest affection was his *Decline and Fall of Wealthy Nations*, printed in 1805.

He had taken out five patents, two of which have been described; a third was for a scheme to take advantage of the wind to bend springs, which were applied to act as reservoirs of power, for increasing the speed of a ship by their reaction.

In the later years of his life he was often reduced to great want, and his friends considered his neglect by government to be a deep stigma on its justice; for they instanced him as being, during his whole life, a consistent and often a powerful and convincing advocate, of loyal principles—and, without hope of fee or reward, he often incurred expenses to promote their dissemination, which his finances could ill bear. In the autumn of 1822, he was released from the prison in which he had been confined many months for a debt (for which he had been surety for a friend) of a few guineas; and had nearly finished a model in relief of the surface of the Holy Land, of which he intended to make a public exhibition, when a disease in his legs, which had made him a cripple for years, took an unfavourable turn, and showing symptoms of mortification, poor unfortunate Playfair

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probably arose from his feeling that he thought and contrived to the best purpose, when his mind was left entirely to itself; though, on the other hand it had the disadvantage that much more time was taken in realizing his ideas than otherwise would have been. The house in which he lived was two miles from Soho, where all the machines were manufactured. To this he seldom went above once a-week, to see what was doing, and when he did go there he seldom staid half an hour."

In this house he had continued to reside, and here, on the 23d of August, 1819, this venerable man closed a life illustrious for its usefulness. "He had suffered some inconvenience through the summer, but was not seriously indisposed till within a few weeks from his death. He then became perfectly aware of the event which was approaching, and, with his usual tranquillity and benevolence of nature, seemed only anxious to

was carried to an hospital for the purpose of undergoing an operation, where he expired on the 11th of February, 1823.

In his best time he had pretensions to elegance both of person and manners; but although he was a man of strong sense, his misfortunes and poverty had no effect in narrowing, or correcting (in the language of the world) the reckless generosity of his heart. Yet his total disregard of money cannot fairly be urged to his blame, for they to whom he stood in the relation of husband and father shared in his mean fortune without repining; feeling, probably, that a life, in which subsistence depends on the result of a succession of precarious speculations, is unfavourable, from its excitement, for the formation and exercise of that steadiness of mind and singleness of purpose which accompany, if they do not produce, habits of caution and self-denial.

He left a widow and four children. One of his daughters was born blind. His eldest son, who held a commission of lieutenant in a regiment which at the peace was disbanded in Canada, preferring to remain in the colony, received from government a grant of land. *See Memoir by Byerley, &c.*

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point out, to the friends around him, the many sources of consolation which were afforded by the circumstances under which it was about to take place. He expressed his sincere gratitude to Providence for the length of days with which he had been blessed, and his exemption from most of the infirmities of age, as well as for the calm and cheerful evening of life that he had been permitted to enjoy after the honourable labours of the day had been concluded. And thus, full of years and honour, in all calmness and tranquillity, he yielded up his soul without a pang or a struggle, and passed from the bosom of his family to that of his God."

"His name fortunately needs no commemoration of ours, for he that bore it survived to see it crowned with undisputed and unenvied honours, and many generations will probably pass away before it shall have gathered all its fame. It has been said that Mr. Watt was the great improver of the steam-engine; but, in truth, as to all that is admirable in its structure, or vast in its utility, he should rather be described as its inventor. It was by his invention that its action was so regulated as to make it capable of being applied to the finest and most delicate manufactures, and its power so increased as to set weight and solidity at defiance. By his admirable contrivances, it has become a thing alike stupendous for its force and flexibility, for the prodigious power which it can exert, and the ease, and precision, and ductility, with which they can be varied, distributed, and applied.

"It would be difficult to estimate the value of the benefits these inventions have conferred upon the country. There is no branch of industry that has not been indebted to them, and in all the most

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material they have not only widened, most magnificently, the field of its exertions, but multiplied a thousand fold the amount of its productions. It has armed the feeble hand of man, in short, with a power to which no limits can be assigned, completed the dominion of mind over matter, and laid a sure foundation for all those future miracles of mechanic power which are to aid and reward the labour of after generations."

"This will be the fame of Watt with future generations, and it is sufficient for his race and country. But to those to whom he more immediately belonged, who lived in his society and enjoyed his conversation, it is not, perhaps, the character in which he will be most frequently recalled, most deeply lamented, or even most highly admired.

"No man could be more social in his spirit, less assuming or fastidious in his manners, or more kind and indulgent towards all who approached him. His talk, though overflowing with information, was full of colloquial spirit and pleasure. He had a certain quiet and grave humour, which ran through most of his conversation, and a vein of temperate jocularity which gave infinite zest and effect to the condensed and inexhaustible information, which formed its main staple and characteristic. His voice was deep and powerful, though he commonly spoke in a low and somewhat monotonous tone, which harmonized admirably with the weight and brevity of his observations, and set off, to the greatest advantage, the pleasant anecdotes, which he delivered with the same grave brow, and the same calm smile playing soberly on his lips. He had in his character the utmost abhorrence for all sorts of forwardness, parade, and pretension; and, indeed, never failed to put such impostors out of countenance by the

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manly plainness and honest intrepidity of his language and deportment. In his temper and disposition he was not only kind and affectionate, but generous and considerate of the feelings of all around him, and gave the most liberal assistance and encouragement to all young persons who shewed any indications of talent, or applied to him for patronage or advice. His health, which was delicate from his youth upwards, seemed to become firmer as he advanced in years, and he possessed, up to the last moment of his existence, not only the full command of his extraordinary intellect, but all the alacrity of spirit and the social gaiety which had illuminated his happiest days."

His remains were deposited in the parochial church of Handsworth, near those of his friend and colleague, the princely Bolton; and, in this temple of peace, filial piety has erected a statue to transmit the corporeal lineaments of a revered parent to posterity.

The piston *a*, of Mr. Turner's steam-wheel, moves in a circular channel or ring *b*, and is attached to the axle *c*, by a thin plate, similar to the piston of Mead's engine. The two abutment valves or sliders, *d*, *e*, recede from the channel into recesses, as the piston approaches them in its revolution, when they are again moved into the channel after the piston passes beyond them. One of the sliders is always placed across the channel while the other is being withdrawn—or during the instant that it is totally within its recess; so that the steam which issues from either of the openings is enclosed between one of the abutment valves and the piston, which is thus carried forward, the opposite opening always forms a com-

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munication with the condenser. When the piston is carried beyond a slider, that slider is moved into the ring, and the other slider begins to be shifted into the recess, at the same time the steam is shut off from one of the openings, and admitted into the opposite one; what was a passage from the boiler is now that to the condenser, and this alteration takes place every revolution. The clever means by which these passages were reversed appears on the engraving; *i*, or *k*, may either be the condenser or steam chamber, and the passages into it are opened or shut by the rise or fall of the lever slide, *n*; a wheel, *o*, fixed on the axis, *c*, communicates the rotary motion to the other machinery. The sliders are shifted by an excentric movement attached to the axle, *c*. A very detailed description of this apparatus, with some excellent illustrative figures, is given in that mine of mechanical inventions,—the Repertory of Arts.

In Mr. Routledge's steam-wheel, the vapour enters the box through the pipe *a*, and a pipe *c*, leads to the condenser. One side of the revolving piston being formed like a curve, in its passage upwards will gradually shut the abutment valve *e*, and as this is pressed downwards by the steam from the boiler, (which flows by a pipe through the valve box,) it will slide down the inclined plane on the other side of the piston, until it comes in contact with the inner cylinder, to which the piston is fixed, and will thus form an abutment valve, until it is again displaced by the piston in its revolution.

Mr. John Malam, who has distinguished himself as an improver of the apparatus for gas-lighting purposes, arranged the parts of his rotary engine in a different manner: to his outer cylinder, which revolved, he fixed three valves, and the piston, which may here be considered as the abutment

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valve, was made of lead, and of a size that would by its weight make it always remain at the lowest part of the cylinder: the three valves in their rotation shut as they approach the piston, and when they have passed beneath it, the steam forces each outwards until it comes into contact with the fixed cylinder, and so on in succession. In the second scheme, there are three circular drums or cases, the outer one forming a jacket to the second, in which the inner one revolves. The area of this is divided by curved partitions like the float boards of a water wheel; each of these chambers, in its rotation, communicates when at its lowest position with the hollow axle, through which steam flows from the boiler, and pressing upon the fluid, fusible metal, or mercury, forces it up one side of the wheel, while the buckets on the other side being filled only with vapour, give a preponderance to the loaded side, which produces a rotary movement. Its principle will be easily understood, by a reference to Amonton's wheel, of which it may be considered as a variety.

Mr. Moore produced a rotary motion, by making the outer case of the circular channel immoveable, and the inner one, which had valves, or propellers fixed upon it, turned on its axis within the fixed case. Steam is admitted by the pipes, *a*, *b*, from the boiler into the steam-channel, and the pipes, *d*, *e*, also connect the channel, with the condenser; the valves, *f*, *g*, are opened and shut by coming into contact with the angular pieces, *h*, *i*. It is obvious, that when steam flows into the spaces, *x*, *y*, if the spaces, *o*, *s*, communicate with the condenser, that the moveable part of the wheel will perform a revolution on its axis. The situation of the different valves in the figure will sufficiently explain their action.

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Sir William Congreve's rotary engine is nearly identical with that which has been described as designed by Bishop, and with the wheel tried at Soho in 1805. Steam was admitted into buckets, on one part of the circumference of a wheel (which was immersed in water), while water was admitted into the buckets on the opposite part of the circumference. This gave a preponderance to one side, which was made continuous by the common mode of valves opening the steam passage to the buckets when they were in a given position. In all projects of this sort it is apparent, that the water or fluid metal in which the wheel revolves, must be kept at a temperature as high as that of the vapour: this, added to the difficulty of preventing the steam from escaping through the fluid without filling the buckets, were objections to this, as they had been to previous mechanisms on the same principle.

The perfection which had been given to the lever-engines on various models, left little inducement to revive the fuel-devouring machine of Savery: but Pontifex's additions made it more convenient, more precise, as a self-acting apparatus, and of better symmetry, and more compact; so that it might be used in some situations with as much economy as even Watt's engine. In pumping water for common purposes, all the heat that it acquires in the operation is lost; but where the water raised is intended to be heated, this which in common cases is a great loss, becomes here a positive gain; and Savery's engine was applied in this manner, at Paris, to raise water to supply some public baths, with a decided economy of fuel.

The next project on the rotary principle, is entitled to a more minute description than has been

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given of some other steam-wheels, from the greater care which has been bestowed to carry the idea into practice. Its inventor, Mr. Thomas Masterman, is a brewer, whose ale is as famous for its exhilarating and substantial qualities, as his mechanical productions are estimable for their ingenuity.

A ring is divided into six compartments by means of as many valves, *a*, *b*, *c*, *d*, *e*, *f*, which are opened and shut in one direction only, by means of a lever loaded with a weight fixed on the axis of each; every compartment communicates with a pipe forming one of the spokes, *g*, *h*, *i*, *k*, *l*, *m*, of the wheel, and running into the nave open on its surface, (as shown in figure 2,) and which is ground perfectly smooth and flat; to this flat surface is fixed another flat plate or mask having three openings: one of these perforations, *z*, opens to a pipe 1, leading to the condenser, the second, *y*, to a pipe 2, communicating with a reservoir of water, or mercury, and the third *x*, to a pipe 3, coming from the boiler. This mask is fixed, and when the wheel revolves, each of the six openings in its nave is brought in its turn opposite each of the three openings in the fixed plate*.

When the wheel is in the situation shown in the figure, the part having the darkest shade is open to the condenser through the spoke *g*, communicating with the perforation *z*, in the mask; the part having the middle tint shade, is filled with steam, which flows from the boiler through the pipe 3, and perforation *x*; and the part which has the darkest shade is filled with water or mercury, through the pipe 2, and perforation *y*, communi-

* Partington, *Hist. Account*, p. 163.

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cating with the spoke; when the weights place the valves in the situation shown in the figure, the steam in one portion of the wheel is condensed; and as a vacuum is made in the upper part, the water rising through the valves on one side of the wheel, causes it to revolve: the perforation which opened to the boiler, is now placed opposite to the condenser, and that which opened to the condenser, communicates with the water cistern, and the steam flows through the spoke which admitted the water, this continues the preponderance; and the wheel makes a complete revolution.

Here, it will be obvious, the power is had by the weight of water in the rim of the wheel, and if it is worked by medium-pressure steam, the fluid column cannot much exceed twenty-eight feet in height; but the horizontal section of the rim may be made of that dimension which will give any required power. It may also be worked with high-pressure steam and a column of mercury of considerable height. Masterman erected some of his engines on a scale of magnitude, but their use has been given up. It was said, that a great deal of heat was lost, by the radiation from the great surface that was exposed to the action of the air; but a very obvious remedy might have been applied—the wheel could have revolved in a non-radiating casing: the difficulty of keeping so great a number of valves steam-tight was a more serious objection, and when used with mercury, it was found that the motion of the wheel comminuted the fluid metal, so that it rose in vapour into the condenser; and the upper surface of the water, (which was much heated,) when that fluid was used, exhaled a considerable portion of steam:—these, however, do not appear objections so very insuper-

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able as to excuse its ingenious author giving up his trials on a beautiful principle to some more persevering rival*.

To those, whose fears were excited at the extension of the practice of operating with steam, of a pressure recommended by Trevithic and Woolfe, the announcement of an attempt to heat water, under a pressure of sixty thousand pounds to each square inch, was sufficiently improbable to be considered as an impossibility, until the eyes of each doubting philosopher should themselves behold it. On view, Perkins, an enterprising American, was found to have vapour of four or five hundred atmospheres more under his controul, than was usually thought could ever be had over any which was generated under a pressure of four or five.

It had been long known, that a prodigous increase of elasticity could be imparted to vapour generated under a great pressure; and practical men were familiar with the fact, that the expense of fuel to produce this additional elasticity did not increase in proportion to the power that was gained by it. But in former experiments, the steam was always raised in contact with the water from which it was produced, which necessarily required boilers of a large size, and to give these large vessels the proper strength, was at all times expensive, and often nearly impracticable.

But this ingenious individual followed a new tract: he subjected water in a vessel to an enormous hydraulic pressure, and in this state, exposed it to a vivid heat; no steam was in contact with it or could escape from it; when he wanted steam, he pumped a small portion of cold water

* *Description of Masterman's Rotatory Steam-Engine*, Lond. 1822. In this the valves are moved in a different manner from those of the figure.

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into the cylinder containing the heated water, which expelled an equal portion of hot water into an empty vessel or cylinder, and the protruded *portion was instantly converted into vapour*. The size of his boiler by this invention was greatly reduced, and the saving of fuel, stated to be made by this mode of producing vapour, was represented to arise from very little more fuel being required to heat water at a pressure of five hundred atmospheres, than it did to heat the same quantity at five atmospheres.

The engraving is copied from a drawing which he exhibited in his workshop, and which was inserted in all the periodical publications of the day: our references to it will extend no farther than to the *generator* and its appendages. The generator, or boiler, is a vessel of copper, three inches thick *a*, having a steel-yard valve *b*. A pipe *c*, is connected with a small forcing pump *d*, the handle of which is loaded with a weight *e*, and another weight *f* acts as an air vessel, *g*, a pipe leading to the working cylinder. When a portion of water is driven by the forcing pump into the generator, the valve *b*, is raised upwards, and a quantity of heated water escapes through it, "and instantly flashing into steam," rushes along the pipe into the cylinder and impels its piston forwards; *i* is a pipe proceeding to an *indicator*, which shows the internal pressure, on inspection.

The celebrated Brunel gave a somewhat novel arrangement to the parts of the common engine. And he placed his two working cylinders in a position so as to form an angle of 102°, and moved their piston rods by the same crank. Its author, however, recommends it, we believe, more for its convenience in certain operations, than from any advantage on the score of economy. Mr.

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Vaughan's atmospheric engine may be described as a double engine on Newcomen's construction, which is formed by using a very long cylinder, divided by a diaphragm in the middle of its length; each half has a piston, and these are connected together by the same rod, *a*. The top of one portion of the cylinder, and the bottom of the opposite one are open to the atmosphere; and the pistons are placed so, that one is at the outermost extremity of one cylinder, while the other piston is at the innermost part of the other. The steam is introduced between a diaphragm and a piston, while the vapour beneath the opposite one is flowing into the atmosphere. This arrangement is nearly the same as that practised by Thompson and other manufacturers, when Watt and Bolton had the monopoly of their condensing engine.

Dr. Alban, a physician of the town of Rostock, in the Grand Duchy of Mecklenberg, generated steam by means of tubes of small diameter, which were calculated to sustain a very great pressure. These pipes were immersed in an easily fusible metal, contained in a cast-iron box; this box was exposed to the fire of the furnace, and heating the metal converted the water in the pipes into vapour. The water was injected into the pipes by a forcing pump, and at each stroke of the engine, as much fluid was thrown into the generators as sufficed to produce vapour for the next stroke;—Alban regulated his injection pump to diminish or suspend its discharge according to the pressure of the vapour in the pipes; "and when it was wished to stop the engine, the forcing pump was merely put out of action." In order to prevent the metal in fusion from being overheated, Alban also introduced a regulator, to correct the intensity of the fire. This mechanism will be found described

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and figured in a treatise nearly ready for publication, on "THE PRINCIPLES AND PRACTICE OF THE CONSTRUCTION OF STEAM-ENGINES." This little book, which will be printed to correspond in size with these anecdotes, will contain numerous *rules* and *tables* for assisting those engaged in the construction and manufacture of steam-engines. In illustration of the text, numerous engravings will be given of the parts, in detail, of machines *constructed* by engineers of eminence. The rules have been drawn from an extensive series of observations on engines in actual use; and their application by *plain men* will be made easy, by the author's adopting a plain manner of stating them.

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CHAPTER TWENTY-EIGHT.

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——— "BUILD HIM
A MONUMENT, AND PLANT IT ROUND WITH SHADE
OF LAUREL, EVERGREEN, AND BRANCHING PALM,
WITH ALL HIS TROPHIES HUNG, AND ACTS INROLL'D
IN COPIOUS LEGEND, OR SWEET LYRIC SONG."

Milton.

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THE expression of public feeling, which Watt's retiring and modest habits had shrunk from and discouraged in his lifetime, found vent at his death. The anniversary of his birth was celebrated by the principal inhabitants of Greenock, on the 19th of January, 1821; and a large subscription was subsequently collected, for the purpose of erecting a statue, to perpetuate their admiration of his virtues and genius.*

* "Several of the principal inhabitants of Greenock formed themselves into a society, and at one of their meetings, in 1821, in testimony of their admiration of the character and talents of their distinguished townsman, it was resolved, that from henceforth it should be called the JAMES WATT CLUB. Having thus honoured the man, the club desired to venerate the house in which he was born; and having ascertained from two of Mr. Watt's old and intimate friends, that he was born in a house lately taken down, to make room for the Greenock Tavern, the club unanimously resolved to hold their future meetings there. Soon after this they changed its name to that of the *James Watt Tavern*, and one of the members, (Mr. John Fleming,) an eminent

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This manifestation of respect, although in perfect unison with public feeling, could only be considered as of a local nature. Public gratitude, which had raised statues in honour of poets, warriors, philosophers, and statesmen, selected Watt as the first of his class, whose genius should be commemorated by the erection, in the metropolis, of a monument worthy of the powerful community which had so largely benefited by his inventions. The KING, the munificent patron of all that is cultivated and refined, had graciously expressed his deep sense of the merits of Mr. Watt, and of the benefits which had resulted to the country from his labours; and, through a generous participation in the national feeling, his Majesty intimated an anxiety that his name should be placed at the head of the list of those who had met to honour the genius of this gifted mechanic. The Earl of Liverpool, who was delegated to convey a munificent donation from his Majesty, in aid of this purpose, took occasion to observe,—"that Mr. Watt was one of the most excellent, as well as

portrait painter, presented the society with an admirable portrait of Mr. Watt, now hung up in the club-room."—CLELAND'S *Hist. Account*, p. 65.

Those mechanic-pilgrims, whose devotion leads them to visit Greenock, will find, that in this *Tavern* they may invoke the genius of Watt, in a shrine which has been described as the Temple of Hospitality. Generous wines, exquisite mountain-dew, and the very choice of the fatness of the land will be spread before them in profusion. After having discharged their duty to the dead, they may cross the ferry to Helensborg, and offer their homage to the living; and from Mr. HENRY BELL, THE FATHER OF NAVIGATION BY STEAM IN EUROPE, they will meet with the most gratifying attention. In this worthy old man they will observe mechanical attainments of a high order, united to a spirit so buoyant and social, that even the pressure of a long series of misfortunes, and the chagrin of public neglect, have not been able to depress or impair it.

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most extraordinary men that this country had produced; that he was to be ranked among the greatest benefactors of mankind, because there are none who deserve more of their country than those who add to the productive powers of industry; and with respect to his private character, there never was a more amiable or more honourable man." But there was another part of his Lordship's address, which gave unfeigned pleasure to those who admired the virtues of the living statesman, and who felt that his honour, as well as the glory of their country, was concerned in the distribution of its personal national distinctions.—"If Mr. Watt," continued the Premier, "did not in his lifetime meet with the *patronage* * and consideration due to his great talents,

* "We feel most deeply the reproach conveyed in the passage extracted from *Dupin's Travels in Great Britain*, that "To a citizen of Glasgow belongs the glory of having given to industry one of the greatest impulses known in the history of the arts. To the improvements invented by the celebrated Watt it is owing, that the steam-engine is become an universal moving power: no invention ever before comprehended, within so small a compass, and at a fourth of the ordinary expense, a power so great, so constant, so regular. In Watt we behold one of the benefactors of his country—yet when I earnestly inquire what brilliant testimony he has received of the national gratitude, my question remains unanswered. It appears, that neither king, nor ministers, nor parliament have yet discovered that they owe any thing to the life and memory of one, to whom the ancients would have erected statues and altars. The ashes of the player Garrick repose under the sacred vaults of Westminster, while the ashes of Watt moulder in a nook of some obscure cemetery."

"The fercible appeal, says the commentator, to the national feeling was not made in vain, nor suffered to remain long unanswered; almost immediately after, M. Dupin has had the satisfaction of seeing the king's first minister and representative presiding and commissioned, by his royal master, to preside at a public meeting for erecting a monument to the memory of James Watt."—*Mechanics Magazine*, vol. ii. p. 242.

Mr. Turner of Godstone, Surrey, with whom we believe the

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it was solely owing to his simplicity of character, the modesty of his nature, the absence of every thing like presumption or ostentation, and that disinclination to obtrude himself, not only on the great and powerful, but even on the scientific

affair originated, in repelling the charges made by M. Dupin, in this extract, and the comment upon it says, "without detracting in the smallest degree from the candour of M. Dupin, who has, with the utmost liberality, borne testimony to the merits of Mr. Watt, I cannot but feel it due to those personal friends of the latter gentleman, at whose instance the measure was brought forward, to state, that at the time it was first agitated, and even at the moment when the public meeting took place, M. Dupin's work alluded to was altogether unknown to most, if not to all of them. The matter as stated in your journal implies a national reflection, as if the country at large had not sufficient discernment to appreciate their obligations to Mr. Watt's talents, and were equally wanting in gratitude to commemorate them. This public meeting was not called by his majesty's ministers; they were applied to by the gentleman with whom the measure originated, in the hope that a parliamentary grant might have been recommended; this, for many reasons, was not deemed advisable; but the Earl of Liverpool and others of his majesty's ministers pledged themselves to support the measure adopted, and redeemed their pledge by their attendance at the public meeting—to which above all they added the sanction of his Majesty's approbation." As to the concluding paragraph of M. Dupin's charge, Mr. Turner properly observes, that "surely the neighbourhood where Mr. Watt and Mr. Bolton lived cannot be obscure—nor could the spot where their ashes repose remain unknown, even if it had not been illustrated by the finest work of modern art."—*Mechanics' Magazine*, vol. ii. p. 306.

Lord Liverpool's declaration, in the text, is a satisfactory refutation of the charge of government having been indifferent to Watt's merits in his lifetime. "His Lordship's statement only gave publicity to the fact, which was known but to a few of Mr. Watt's friends, that a personal distinction had been offered to him. We know not which is most to be envied, the feelings of the statesman who had the discernment and patriotism to offer a performance of this duty, or those of the individual whose self-denial made him decline the proffered honour."

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world, of which he himself was so great, so bright an ornament. I feel much satisfaction in being able, from my own *personal knowledge*, to say so much."

"The Archimedes of the ancient world, by his mechanical inventions," Sir Humphrey Davy remarked, "arrested the course of the Romans, and stayed for a while the downfall of his country. How much more has our modern Archimedes done. He has permanently elevated the strength and wealth of this great empire, and his inventions have enabled Britain to display a power and resources infinitely above what might have been expected from the numerical strength of her population. Archimedes valued principally abstract science. Watt, on the contrary, brought every principle to some practical use, and, as it were, made science descend from heaven to earth. The great inventions of the Syracusan died with him; those of our philosopher live, and their utility and importance are more daily felt: they are among the grand results which place civilized above savage men, which secure the triumph of intellect, and exalt genius and moral force over mere brute strength, courage, and numbers."

Mr. Bolton, the son of Watt's celebrated colleague, said, "that at the period of the construction of the first condensing steam-engine at Soho, the intelligent and judicious Smeaton, who had been invited to satisfy himself of the performance of this engine, by his own experiments upon it, had been convinced of its superiority over Newcomen's, doubted the practicability of getting the different parts executed with the requisite precision, and augured, from the extreme difficulty of attaining this desideratum, that their powerful machine, in its improved form, would never be

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generally introduced; and the low state of the mechanic arts, at that period, fully justified his opinion. But a body of workmen was speedily formed, and the parts of the machine were fabricated with a skill and accuracy, till then unknown in the construction of massive machinery. The effectual adaptation of the condensing engine to the varied operations of our manufactures, and which is now almost a matter of routine, was attained by the efforts, continued for a succession of years, of a deeply reflecting mechanical mind, and by a series of ingenious experiments throughout the whole scope of British manufacture. In this investigation Mr. Watt had the co-operation of some highly enlightened colleagues, to whose merits and exertions he has paid a just tribute of acknowledgment. A power equal to that which would require the maintenance of one hundred thousand horses, has been furnished from *Soho alone*, and assuming that power to be exerted during three hundred days in the course of the year, the saving arising from the substitution of steam power in lieu of the exertions of the animals themselves, would not be less than two and a half millions of pounds per annum."

"I should be wrong," said Mr. Huskisson, "if I remained silent; for it is a gratification to feel that such a man was born in this country; but it is a still greater gratification that we lived in the same age with him, and had an opportunity of enjoying all the benefits and advantages which he, under God, has been the instrument of conferring. He who doubts Mr. Watt's rights to be placed in the first class of men of genius, has not properly reflected upon the influence of chemical and mechanical science on the moral condition of society. By his invention labour was abridged,

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and the manufacture was executed with perfection and rapidity; and in the almost indefinite production of every article, the wishes, the wants, and convenience of every people were suited. By this the moral condition of mankind is improved, for by creating new wants in the minds even of savage nations, you infuse new ideas, and a spirit of exertion, which will stimulate them to industry and an improvement of their condition; and if the former savage of Otaheite has now exchanged his nakedness for the linens and cloths of England; and if the articles of his household furniture be changed in the same way, it is mainly owing to the facility the steam-engine affords of manufacturing these articles at a cheap rate, and with great celerity; and it has thus acted as a great moral lever to raise a degraded, and before uncivilized, people to a state of comparative civilization and a sense of independence; and but for those important mechanical and scientific inventions, making, as they did, a gradual, silent, but certain accession to the wealth and industry of this country, we might have been obliged to sue for a humiliating peace before all the energies of Nelson were called forth at Trafalgar, or before the military sway of Napoleon was broken down by the Duke of Wellington, and the seal set to the peace of Europe by the battle of Waterloo."

"I may refer," says Sir James Mackintosh, "on this occasion, to one of the greatest philosophers this country ever produced,—my Lord Bacon, who in his New Atlantis, a work, I believe, but little read, describes a voyage to an imaginary country, in which he mentions what he calls Solomon's house, and sometimes the college of the six-days' works. In that house he describes a magnificent

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gallery for men of science, a part of which is filled with the statues of inventors. The great and unrivalled wisdom of that philosopher did not disdain to place, among the first rank of the cultivators of science, those inventors who benefited their country by their inventions. In one place was seen the inventor of glass, in another the inventor of the management and use of the silkworm. What place, I would ask, would my Lord Bacon have given to Mr. Watt had he lived in his time? He would undoubtedly have placed him at the head of all inventors of all ages. That great philosopher goes on to state, that whereas lawgivers, extirpators of tyrants, fathers of their country, and the like, are honoured as demigods, inventors are honoured with the title of gods. But sixty years have elapsed since the introduction of this great power, and a much shorter since Mr. Watt applied it to the purposes of practical utility; let us look over the globe, and we now find its powers every where in motion, in the bowels of the earth, upon the highest mountains, upon the face of the waters; all the great rivers of South America are now navigated by steam, so that the savage who inhabits the forests of Guiana becomes alarmed at the appearance of a monster, which makes its way upon the waters, without apparent effort or moral agency. If so much has been done in so short a time, what may not a sanguine hope whisper to itself as to the future. I entertain trembling hopes which I would not wish to expose to the eye of the scorner, but I feel that still nobler things are reserved in the unopened volumes of destiny." Mr. Brougham felt "that he might safely call on those who were acquainted with Watt's domestic habits, to bear testimony to his private worth; nothing," he con-

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tinued, "could be more pure, more simple, or more scrupulously loving of justice, than his conduct in every situation; it was hard to say which was most to be admired, the extent of his understanding, or the nicety with which he was able to reduce it to the smallest circumstances,—while it could expand to the greatest designs, it could at all times descend even to the niceties of verbal or classical criticism. He was eminently distinguished, too, by the total want of jealousy in all his proceedings; he was conspicuous for a most careful self-denial in all his actions, lest he should appear to be desirous of appropriating to himself the honour that was due to others. It was this that always made him decline what every body was willing to concede to him, the honour of being called the inventor of the steam-engine—contenting himself with the title of its improver, though to doubt of his right to this honour were as absurd as to doubt the original genius of Sir Isaac Newton, because Descartes in one line, and Galileo in another, had preceded him. Mr. Watt took peculiar delight in adjusting the conflicting claims of others to scientific discoveries, and giving to each individual his due, and though he was a man of the mildest temper, he was always ruffled by adulation towards himself, or ascribing to the genius of one what was justly the property of another. It is to do honour to all these rare excellencies of character that we are now assembled to vote a monument to his memory; not that a monument is wanting to immortalize him, for his memory will be as lasting as the power which he subdued to the use of man; but to consecrate his example before the world, to hold forth to others, that a man of transcendent genius cannot better employ it, than in conferring a benefit on all mankind:

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and where can the monument of this great man be more appropriately placed, than in a temple of that religion which teaches peace to all. The temples of the pagans were adorned by statues of warriors, who dealt desolation on their race; but ours shall be graced with the statues of those who have contributed to the triumph of humanity and science; and, among others, to him who has achieved what has been an honour and a benefit to the human race."

Mr. Littleton had endeavoured to ascertain data from which to estimate the total saving made by steam-engines. The number of steam-engines may be near the mark if stated to be about ten thousand; and taking these, on an average, to be about equal to twenty-horse power each, we have two hundred thousand horses acting together for a total power employed in manufactures, mines, &c. during a period of from ten to twenty-two hours per day: there must have been from two to two and a half sets of horses to perform a work of this description, which would raise the total number to between four hundred and five hundred thousand horses. The difference of cost between the coals consumed by these engines and the keep of that number of horses would amount annually to above twenty millions of pounds sterling. If the calculation were carried further to the saving in *actual labour*, there would be a result almost incredible.

Mr. Peel observed, "that he was one of the numberless persons who had derived a direct personal benefit from the inventions of Mr. Watt,—from the cotton trade, which had received fresh life and spirit from the introduction of the steam-engine: before the year 1790, the manufactories had existed in remote districts, and depended

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almost entirely on the exertion of animal or water power; but the improvement of the steam-engine transported the factories, from wild and inaccessible places, to towns and cities, and enabled every branch of the process to be united under the same roof, so that in a wonderfully short time the raw material is converted into the finished cloth. When I recollect what took place thirty years ago, and look at the fortunes that have been made, the towns that have sprung into existence, I cannot but offer my unfeigned admiration to the genius which has produced this effect. I feel that the class of society, from which I have risen, has been ennobled by Mr. Watt's genius; but it is less on that account than of the honour which he has conferred on the whole nation, that I join in the wish to see his statue among those of our illustrious dead." The Earl of Aberdeen, Mr. Frankland Lewis, and Mr. Wedgewood expressed their entire concurrence in the opinions of those who had preceded them; and Mr. Wilberforce congratulated the Earl of Liverpool, that his presiding on this occasion was a proof that his Lordship recognized the proper use that was to be made of superior rank and station. "It is the glory of the country in which we live—a glory, to which, in the whole history of the world, no country was ever before entitled in so eminent a degree—that individuals, by the honourable exercise of their own superior talents, and virtuous industry, may rise to the highest rank, and most abundant affluence. It is to the free constitution of this country, it is to the enjoyment of equal laws, that we owe these blessings; and many an ingenious man, in a humble and obscure situation, may be cheered and animated in his toilsome and exhausting course, by calling to mind this day's pro-

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ceedings, and by feeling that, by travelling the same path which he travelled, whose genius we have assembled to commemorate, he will reach the same goal of glory and honour."

Meetings to co-operate in the same grateful work were shortly afterwards held at Manchester, Edinburgh, and other places. In that which was held at Glasgow, Professor Jardine said, that "though men of genius may be said to be properly of every country, those of the same country consider themselves as having a particular interest in them. We have a particular interest in Mr. Watt; he belongs to this part of the country by birth and education; and we feel, like others, some shade of conscious pride in this claim of ours, as to whether there should be separate monuments in different places, or one great, and magnificent one in the most appropriate place: I acknowledge, my leaning is to one great, magnificent, and sublime monument which shall command the attention of all. I am for a monument which shall be durable, and such as shall wear out the teeth, as has been well said, of envious Time;" but after the meeting was addressed by the Lord Provost, Mr. Henry Monteith, Mr. Kirkman Finlay, Mr. James Ewing, Mr. William Smith, Doctor Thomas Thomson, Mr. Henry Houldsworth, and Doctor Andrew Ure, it was resolved, that, in consequence of the early connexion of Mr. Watt with their city, they should erect a *separate* monument to perpetuate the circumstance—not that fifty years ago the corporation had expelled him from its jurisdiction, but because since that time his fame had grown so great, that it reflected honour on themselves as living in the same city of which he also in his youth had been an inhabitant.

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If national distinctions are conferred with the view of exciting emulation, yet there are few principles in legislation founded on a surer basis, than those leaving individual enterprise solely to its own exertion for its ultimate reward. To remunerate, from public sources, the loss attending a failure in projects undertaken with the spirit, and for the purposes of individual gain, were to hold out a premium to a defective, or a too sanguine, judgment; and yet there have been cases, in which an undeviating observance of this salutary maxim would have been as unfeeling towards individuals as impolitic to the best interests of the state.

Prompted by this feeling, exceptions have been made to the general rule, and some projectors have been looked on with favour, who, by their own act, were beyond the pale of any claim whatever to a compensation from the public; for by entrenching their right with a patent, they virtually refused to the community any participation in the benefits arising from their invention, excepting with a reservation of emolument to themselves. Government has even sanctioned a grant to a patentee, after the expiration of the renewed term, which Parliament had extended to the duration of his patent, on purpose to assist him in reaping personal benefit from his ingenuity; although that extension was all that a patentee could claim, and, it may be added, was all that, under any circumstances whatever, the most liberal government ought to have bestowed.

Other exceptions to the general principle have been made on less objectionable grounds; for instance, where the improvement was of importance to the public, but was of such a nature as to render

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it impossible to protect an exclusive interest in it—after a patent had been granted, a fair claim was urged to some compensation. In another case the indemnity sought was for a project, also of moment, which had been thrown open to the public, without the inventor applying for a patent at all. Nay, parliament has even rewarded an individual, who had previously accumulated a fortune by carrying his improvement into practice. The grant to the improver of our roads was made under these circumstances; in Mr. Macadam's case there was no exhibition of genius or inventive power. This indefatigable American did not even claim any originality in his practice.

The most extraordinary circumstance connected with the generous interposition of public sympathy in softening the rigour of a principle, where its operation might press with undue severity, is that very few demonstrations of this compassionate feeling have been made in favour of that meritorious class, from which alone all candidates for public reward should be taken,—from among those who, either from poverty or patriotism, had not taken legal steps to appropriate the benefits of their improvements to themselves; but after having exhausted their resources in experiments, of which their country was reaping the benefit, they were left to pine in indigence and in obscurity. In our own time, the benefits flowing to the nation from one improvement have been so splendid, as even to obscure the name and services and merit of the very man by whose enterprise it was introduced, and who has only reaped ruin from what has made the fortunes of many, and added to the enjoyment and

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convenience of hundreds of thousands of his cotemporaries.

One of the topics which forcibly arrested the admiration of all those powerful and learned persons, who paid their homage to the genius of Watt, was the introduction of steam-power into navigation. Are they too sanguine who see in its further development a great revolution in naval tactics—in the attack and defence of kingdoms—in the importance of ancient maritime stations—in the increased energy given to internal improvement—in its international effects, uniting countries and places which Nature had disjoined, and which natural causes would for ever have acted to continue the separation; "gathering in, as it were, the nations in harmony with each other, in love and unity and peace and concord;" already a power, probably equal to a sixth part of all the steam-engines in being, is appropriated to propelling vessels. At the end of 1823, there had been ninety steamboats *built in Scotland*, the cost of which, averaging about four thousand pounds each, will give an amount of three hundred and eighty thousand pounds of sunk capital; of that number forty-five were sold from the Clyde. In the year previous to this, *fifty-five steam-vessels were plying* in Scotland, thirty-two of them belonging to the Clyde: supposing these fifty-five vessels to employ five hundred and fifty men and officers, their yearly wages will amount to thirty-two thousand pounds; the coals consumed to thirty-two thousand; harbour dues, six thousand five hundred pounds; tear and wear on all the boats, twenty-two thousand pounds; profit on capital invested at ten per cent.: altogether, this is an annual dis-

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bursement, which proves the receipt of one hundred and fourteen thousand pounds per annum for the fare of passengers on the rivers of Scotland; and if we only estimate each passenger to pay four shillings, this will give nearly *six hundred thousand persons* who, in one year, have availed themselves of the convenience of a steamboat.

But if we extend the calculation to all the steam-boats in Britain, the result will be altogether magnificent. At this moment the capital sunk will not amount to less than three millions, and the annual income must exceed six hundred thousand pounds annually; and this amazing progress has been made in a period of not more than nine years, and steam navigation is still extending so rapidly that we are justified in considering it to be, as yet, in its infancy. At present, we may have an idea of its direct extension, but who can tell the ramifications in which it already begins to influence every thing in the nature of commercial intercourse. Yet in this glorious race, the original father of the design, Mr. HENRY BELL, was fated to be not only distanced by his rivals, but *to be ruined in the competition, and reduced to indigence.* His own account of his misfortunes pleads forcibly in his favour:—"I opened up," says Mr. Bell, "most of the different stations where steam-boats ply, and all this single-handed. I sold the first steam-boat that went to London, and also the first that went to France. The COMET was lost on the 15th of December, 1820, on the west coast of Scotland; and, on the 9th of September, 1821, another steam-boat of mine was burnt down to the water's edge on a Sunday morning, while lying at anchor. Neither of the two

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were insured; and, independent of this, I experienced a great loss, in opening up all the different grounds single-handed, which as soon as they were seen to pay, induced large and powerful companies to embark in steam-boat speculation, with larger boats and greater power, so that they could go quicker, and, of course, I, and my steam-boats, were left behind; but I have almost served my day and generation, as my supply of fuel is now getting small, my steam is getting weaker, and, at last, my capacity of making way must cease. I have been these six months laid up in dock under repairs, but should the Head Carpenter give the order that all is right, I may once more be launched afloat."

Mr. Bell was happily restored to health, but a renewal of physical strength brought no accession to his pecuniary resources; and since that period, it is feared, they have not been in a more prosperous condition. One hope, however, may still be cherished, that should his case meet the eye of any of those powerful and generous persons, who did themselves and the country so much honour, by the zeal with which they eulogized the inventions and merit of Mr. Watt, they may be induced to extend their assistance in bringing the claims of a neglected and deserving man before the public; for, next to the great improver of the steam-engine, he may be considered as that individual who, in Europe, led the way to its most important application. A FARTHING ONLY from each person who, during one year, made a voyage in a steam-boat, would place this meritorious and worthy man (the moderation of whose wishes is said to be equal to his other merit) in a situation to look

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upon the infirmities of old age without an apprehension, that as his useful, but chequered, life approaches its natural termination, penury may not be added to neglect in imbittering its final close.

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CHAPTER TWENTY-NINE.

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"NATURE IN HER PRODUCTIONS SLOW, ASPIRES
BY JUST DEGREES TO REACH PERFECTION'S HEIGHT;
SO MIMIC ART WORKS LEISURELY TILL TIME
IMPROVE THE PIECE, OR WISE EXPERIENCE GIVE
THE PROPER FINISHING." *Somervile.*

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A SINGULAR attempt to deviate from the beaten track, and employ another agent than steam to raise a piston, was made in 1791, by Mr. Robert Street, who described an apparatus, in which turpentine falling on a hot iron was raised into vapour, that was afterwards inflamed in a cylinder beneath a piston, which was raised by the impulse of its expansion. Street considered this could be used as a prime mover, with as much economy as steam.

A still better application of a similar idea was made by M. de Rivaz in 1807. A cylindrical vessel 4½ inches in diameter was fitted with a piston. At the bottom of this cylinder was a smaller one also fitted with a piston, the rod of which descended downwards, and was attached to the middle of a horizontal lever, by which it might be moved upwards or downwards. This piston had a perforation which was closed with a valve opening downwards; from the top of the small

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cylinder, a short tube passed horizontally outwards, having a skin bag filled with hydrogen gas fixed at its external end. This tube had also a cock with two passages, one of which admitted the hydrogen, and the second common air, and its third position prevented all external communication.

To charge this apparatus with the explosive mixture, the lower piston is to be raised by the lever until it touches the upper piston, which will cause all the air between the two to be expelled through the lower valve, which is to be opened for that purpose. When it is made to descend, the cock in the horizontal pipe is opened, and it will draw in at pleasure a quantity of hydrogen gas, and of common air, in the proportions of sixty inches of hydrogen, and one hundred and twenty of common air, or thirty inches of "vegetable hydrogen," mixed with one hundred and eighty inches of common air, sufficient to work a piston of eleven pounds weight regularly. De Rivaz moved a locomotive carriage by the power he derived in this manner: he also inflamed the gaseous mixture, by transmitting the electric spark to a button, from which it was conveyed sideways through a thick wire, to a plate at the bottom of the upper piston; "the explosion instantly took place, and the piston was driven far upwards, when the dose of the fulminating mixture was sufficiently powerful." The apparatus, it is clear, may be charged with any kind of aëriform and concrete substances capable of explosion.

For this scheme a patent was granted by the French government in 1807, but it was not published before 1824, four years after the period when an idea of procuring a motive power from the inflammation of a mixture of air and hydro-

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gen, was carried into practice by the Reverend Mr. Cecil of Cambridge. In 1820 this gentleman exhibited a model of his machine, and in the same year gave a minute and detailed description of its construction and effects, in the "Transactions of the Cambridge Philosophical Society." From this lucid account the description and drawing is extracted: indeed, nothing can be fuller or better developed than this fine essay, which considered as the production of one whose ordinary pursuits are far removed from those connected with the combination of machinery, it is one of the most estimable first attempts with which we are acquainted.

"It may safely be laid down," says Mr. Cecil, "as a principle, that any explosion may be safely opposed by an elastic force, (the force of condensed air for example,) if the elastic force has little or no inertia connected with it; on the contrary, the smallest quantity of inertia exposed to an exploding mixture *fully ignited* is nearly equivalent to an immovable obstacle. Thus a small quantity of gunpowder, or a mixture of oxygen and hydrogen, may be safely ignited in a large close vessel filled with air; for the pressure of the exploding substance against the sides of the vessel can never be much greater than the elasticity of the air which it condenses.

"If a small quantity of card, or a piece of paper, be inserted in the middle of a gun charged with powder only, the gun will commonly burst upon being fired: for in this case the powder after being fully ignited comes to act upon a body at rest having inertia; and such a body cannot be moved out of the way in an indefinitely small time, without a force indefinitely great; or it is equivalent to an immovable obstacle.

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"Of all exploding mixtures, therefore, having the same field of expansion, those are the most dangerous, and the least adapted to produce a moving force, which are ignited with the greatest rapidity. Thus a mixture of oxygen and hydrogen, of which the ignition is extremely rapid, is far less adapted for such purposes than the mixture of common air and hydrogen, which is ignited more slowly. There is scarcely any exploding mixture which is ignited so slowly as gunpowder; this, therefore, notwithstanding its great force and field of expansion, is peculiarly adapted to produce either momentum or moving force: but great care must be taken to place the mass opposed in close contact with the powder, so that the exploding force may begin to act upon it the instant the ignition commences, and that the action may cease before the ignition is completed. In a common musket, if a ball be placed at a short distance, the gun will burst, as it becomes an immovable obstacle. It is here supposed that the exploding mixture has itself no inertia, or that it is capable of following up the body, on which it acts with a velocity incomparably greater than that body can acquire."

A small steam-engine, not exceeding the power of one man, cannot, Mr. Cecil found, be brought into action in less than half an hour; and a four-horse engine in less than two hours preparation. The engine in which hydrogen gas is employed to produce moving force, was intended to unite two principal advantages of water and steam, so as to be capable of acting in any place without the delay and labour of preparation.

"The general principle of this apparatus is founded upon the property which hydrogen gas mixed with atmospheric air possesses of exploding upon ignition, so as to produce a large imperfect

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vacuum: if two and a half measures, by bulk, of atmospheric air be mixed with one measure of hydrogen, and a flame be applied, the mixed gas will expand into a space rather greater than three times its original bulk. The products of the explosion are a globule of water formed by the union of the hydrogen with the oxygen of the atmospheric air, and a quantity of azote, which in its natural state constituted 1.556 of the bulk of the mixed gas. The same quantity of azote is now expanded into a space somewhat greater than three times the original bulk of the mixed gas; that is, into about six times the space which it before occupied: its density, therefore, is about one sixth, that of the atmosphere being unity. If the external air be prevented, by a proper apparatus, from returning into this imperfect vacuum, the pressure of the atmosphere may be employed as a moving force, nearly in the same manner as in a common steam-engine; the difference consists merely in the way of forming the vacuum.

"Any quantity of pure hydrogen gas will produce more than five times the effect of the same bulk of steam, and in practice their disproportion is still greater. It is here supposed that steam produces by condensation a perfect vacuum equal to its own bulk, but this is far from being the case; much of the power is lost by needless condensation, by the escape of steam through the piston, besides a considerable deduction for working an air-pump, and two water-pumps, which are necessary to a steam-engine: if a close cylinder, ten inches long and two inches in diameter, be made of thin tin, seamed up one side, and close soldered, the ends being well secured, it will easily sustain without bursting the whole force of the exploding

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mixture: the internal pressure against the sides of the vessel, in this case, is about one hundred and eighty pounds to the square inch, or twelve atmospheres nearly; but if an explosive mixture, having a pressure of twelve atmospheres, be allowed to expand into a space rather more than three times its original bulk, its initial force is at an end, and it balances the weight of the atmosphere equal to fifteen pounds on the square inch, for the exploding force varies as the square of the space occupied by expanding fluid. The model of this gas engine was found to work very freely when hydrogen did not exceed one fifth of the mixed gas; but its greatest effect was obtained when hydrogen formed two sevenths of the mixture."

A, B, C, D, a long, narrow, vertical cylinder, divided into two parts at *a, b, d*, so that the upper part A, B, *a, b*, may be one third part of the whole cylinder. In the partition *a, b, d*, is a large circular hole, covered by a choke valve, turning upon an axis *a, b*, which passes through a small stuffing-box at *a*, on the side of the cylinder. At the point *e*, in the axle *b, a*, produced is an upright handle *e, f*, connected by a cross bar, *f, r*, with the lever *q, r, s*, moveable about *q*. In the upper division A, B, *a, b*, of the cylinder, is a piston *g, h, k*, connected by two upright rods F, H, G, K, jointed at their extremities with the horizontal frame N, L, H, moveable about the fixed axle L, M. The frame is connected at the point N, with a crank on the axle P, Q, which carries a fly wheel at P. Immediately above the partition *a, b, d*, a pipe *n, o*, enters the cylinder from a vessel containing hydrogen gas, which is mixed with common air by an apparatus already described. Upon the pipe *n, o*, is a stop-cock, which is opened upon the appulse of the piston to the partition

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a, *b*, *d*, and shut again upon its appulse to the top of the cylinder. At C, D, is a light valve R, S, T, described above, moderately air tight and opening downwards.

The piston, during its ascent, draws in from the pipe *n*, *o*, a charge of mixed gas, which is exploded on the appulse of the piston to the top of the cylinder by the flame of a gas-light absorbed at the touch-hole *c*, which is opened for a single instant by the motion of a small sliding plate. The common air is expelled from the lower division *a*, *b*, C, D, of the cylinder at the valve R, S, T, leaving an imperfect vacuum density, one sixth in the whole cylinder, A, B, C, D. The piston descends from = A, to *a*, by the pressure of the atmosphere, and is raised again by the momentum of the fly-wheel, being followed in its ascent by a fresh portion of mixed gas, drawn in from the pipe *n*, *o*. The upper division A, B, *a*, *b*, is a cylinder of brass, accurately bored; the lower division *a*, *b*, A, C, D, requires no accuracy of bore and but very little strength. It may, therefore, be made of sheet copper, with a strong flange at the bottom, presenting a flat face to the valve R, S, T. To remedy the noise which is occasioned by the explosion, the lower end of the cylinder, A, B, C, D, may be buried in a well; or it may be enclosed in a large air-tight vessel: this vessel will be filled with condensed air, expelled, together with a quantity of water from the cylinder *a*, *b*, C, D. This condensed air may be made to co-operate with the vacuum in working the engine, and will occasion a considerable increase of power without adding to the friction.

"In the model, power is had from the pressure of the atmosphere upon an imperfect vacuum; but an engine may be constructed to work with an

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exploding force only, or by the exploding force and pressure of atmosphere jointly."

The manner in which Mr. Samuel Brown produced a power, from the inflammation of a mixture of air and hydrogen gas, was similar in his first trials to the method shewn by Cecil: but here his second and greatly improved mechanism will be selected for description.

The inflammable gas is conducted by a pipe *a*, to a burner *c*, fixed in a cylinder *c*, which is inclosed by a another cylinder *d*, having a groove made at its upper part, into which a cover *e* falls; this cover has a small valve *n* opening outwards. The pipe *f* opens a passage for the atmosphere, and the inner cylinder *c*; *g* is a vibrating lever to which the covers are attached; *h* another vibrating lever or cylinder, which acts to open and shut the cocks on the pipes *f*, *a*; *i*, a pipe proceeding from the inner cylinder into a reservoir; *k*, *l*, two rods attached to the greater vibrating lever, having hollow floats at their other extremity, which rise and fall in the reservoirs *m*, *m*; *o*, *o*, valves opened by the rods *p*, *p*; *q*, a valve on a pipe *r*; *s*, a pipe proceeding from the gas pipe at both ends; the gas is kept constantly inflamed. Gas is admitted through the holes in the burner *c*, and flowing into the open cylinder mixes with the air, and at the same time the valve *q* being opened, the flame communicates to the mixture of gas and air in the cylinder—at the moment of inflammation the cover is pressed down, and the valve *q* is closed, a part of the heated air escapes through the valve in its top; the water from the reservoir rises up the pipe *r*, and flows into the inner cylinder, whence it escapes through the pipe *t* upon a wheel, or into a reservoir; during this operation, the cover of the other cylinder is being lifted up,

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for the water in the pipe *u*, falling into *w*, raises the hollow float in the reservoir *m*, and in its ascent the tappets fixed upon it open the valves on that side of the mechanism, and reversing the position of those which have just been described, bring the parts of the opposite cylinder into action, and thus continue the working stroke of the engine.

The inventor also explained a method of working pistons, by making a vacuum in each cylinder alternately, either above or below them.

Brown, although he failed in introducing his machine, received liberal assistance in establishing its powers, by experiment on a large scale. A company was formed to carry the scheme into execution, and ample funds were placed, for that purpose, at the disposal of certain individuals of respectability. The trial was made in the presence of these parties to move a boat, and they were perfectly satisfied that, as far as the power went, it was as effective and precise as steam. But in their opinion the great expense of the gas would entirely prevent its coming into competition with steam, as an economical power; and, from the nature of the machine, it must on this account yield even to Newcomen's engine. The construction of the machine, and especially the inflammation of the gas in an open vessel, present many difficulties to a correct explanation of the means by which the effect was produced; much that has been written on this subject is mere conjecture, and the discussion added no new facts or reasonings to those contained in Cecil's description of his model. They who are seeking information, with regard to the peculiarities and advantages of a motive power produced by the inflammation of a mixture of air and hydrogen

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gas, will find it worth their pains to refer to Cecil's account of his experiments.

In adjusting the claims of Cecil and Brown, the first it must be remembered exhibited and described his model in 1820. Brown said nothing of his before 1823, and a greater time elapsed before his model was exhibited to the public; but if priority of idea be due to the machine of the scholar, Brown's supplies parts which make it more practical. And though the claim of invention rests with Cecil, Brown must be commended for his emendations. By producing combustion in an open vessel, Brown insured the most perfect safety to the apparatus; but probably this alteration cannot be considered to have been an improvement, when viewed with reference to the economical application of the exploding mixture.

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CHAPTER THIRTY.

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"THEY WHO AIM VIGOROUSLY AT PERFECTION, WILL COME NEARER TO IT, THAN THOSE WHOSE LAZINESS OR DESPONDENCY MAKES THEM GIVE UP ITS PURSUIT, FROM THE FEELING OF ITS BEING UNATTAINABLE."—*Chesterfield.*

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Mr. Faraday, in his experiments on the compressibility of the gases, found that liquid carbonic acid at a temperature of 32° exerted an expansive power equal to that of air compressed with a weight of thirty-five atmospheres; and that an increase of heat of from 12° to 32° gave a difference in expansive power of nearly thirteen atmospheres, and at higher temperatures the increase was upwards of twelve pounds weight, on each inch, for every additional degree of heat.

The task of turning this amazing elasticity into a means of obtaining a portable and powerful mechanical agent was delegated to the celebrated fabricator of the block machinery; and Brunel's was a very simple mechanism. The fluid gas was heated by means of pipes filled with hot water or steam; and cooled by allowing cold water to flow through the same channels, and the difference in volume between the fluid gas at the two temperatures will be the power developed in this mechanism.

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Brunel arranged five cylinders, so that the two external ones should contain the fluid gas; the next two were what he called expanding vessels, and the middle one the working cylinder fitted with a piston.

The receiver *a*, is a vessel of thick gun metal, firmly closed at top and bottom; thin copper pipes *b*, *b*, pass through it, which terminate at top and bottom, in a chamber *c*, *c*. These chambers have a communication with two pipes, *e*, *f*, *g*, *h*, the pipes *e*, *g*, supply cold water, *f*, *h*, hot-water or steam; the cocks *i*, *k*, shut off the communication between the one set of pipes, and open it with the other; the cock *m* opens or closes the passage of the fluid gas, to flow into the expanding vessel *n*, in which *o* is a float, resting on the surface of the oil, and *p*, a pipe connecting it with the working cylinder *q*.

In the figure, the hot water is flowing through *g* into the chamber *c*, and thence through the pipes into the receiver, and escapes through the pipe *h*. The fluid gas being heated, is expanded and flows into the vessel *n*, which forces the oil downwards through the pipe *p*, into the working cylinder, and raises its piston; the cocks are now turned, and cold water flows through pipe *a*, into the chamber *c*, into the pipes inserted in the gas, and the volume of the gas is then diminished. At the same time that this operation was reversed, the fluid gas in the opposite cylinder was heated in the same manner, but the expansive vessel communicated with the top of the cylinder, and it was thus pressed downwards, and the cooled gas in the cylinder was again forced from the expanding vessel into the first cylinder, to be heated when the piston had made its movement; the cold water would also be introduced in its turn into the second vessel.

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Even in hands so noted for ingenuity, it is still problematical whether the expanse of heat may not be as great on this as on any other arrangement.

Barton's piston is an improvement on Cartwright's, and is much in use. Its most approved construction will be shewn in the *Treatise on the Principles and Construction of Steam-Engines.* Jessop's is a spiral hoop to wrap round hempen packing; by screwing down the upper and lower plates of the piston it is pressed outwards, and bears more or less against the sides of the cylinder. This also will be described in the treatise alluded to.

In Howard's alcoholic vapour engine the two cylinders *a*, and *b*, were connected to each other by the pipe or trough, *c*, a piston was fitted into *b*, and open on its upper surface to the air. The other cylinder was closed at top. From this proceeded a pipe, *d*, that formed a communication with a condenser. Another pipe, *e*, was the continuation of a small forcing pump. One of the cylinders was nearly filled with oil, and a flat thin metallic dish floated on the surface of the oil in the closed cylinder. Lamps, *f*, *g*, were placed under the bottoms of the cylinders, and heated the oil. A small quantity of alcohol or ether, being thrown upon the dish, (heated from its contact with the oil,) vapour was generated, and as this accumulated it displaced the oil, and pressed it downwards through the pipe or trough, *e*, into the cylinder, *b*, and raised its piston: when the oil had been nearly expelled from one cylinder into the other, the flow of alcohol or ether through the pipe, *e*, was stopped, and a communication was opened with the condenser by means of the pipe, *d*;—a vacuum is thus made above the floating dish in the cylinder *a*, and the pres-

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sure of the atmosphere on the piston, *b*, forced it downwards, pressing the oil beneath it through the trough into the first cylinder: when that vessel was nearly filled with oil, the passage to the condenser was closed, and the fluid pipe was opened—a fresh portion of alcohol was thrown upon the floating dish, which being converted into vapour, it again pressed the oil downwards in one cylinder, and upwards in the other. The alcoholic vapour which flowed into the condenser was condensed by coming into contact with a metallic vessel immersed in cold water; and the reproduced fluid falling to the bottom was pumped up through the pipe, *e*. No more vapour was produced by this mechanism, than was necessary for each stroke; a boiler was dispensed with, as the expansion took place in the cylinder itself; the vapour being re-condensed without the access of air, or mixing with the water, when the apparatus was charged with alcohol,—its expansion and condensation, under those circumstances, being produced alternately, all waste of the fluid was prevented.

Captain Walter Foreman's steam-wheel differs from some others we have described, in having a wheel *a*, to shut the valves *b*, *c*, down as they approach the abutment *d*, and in the valves being formed conical to prevent the friction of those usually called rectangular ones. *Eve's* wheel is an alteration of Flint's, and his second scheme, of Murdoch's, but with a decided improvement; these have been tried on a great scale, and are said to answer. The operation will be apparent from an inspection. The Marquis de Combis' is the same as Bramah's first scheme. To which also may be referred Mr. Elijah Galloway's; but this last has pretensions to more practical merit than

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almost any other on the same principle. The mode of bringing the sliders to rest by means of springs, and the neat and artist-like arrangement of the whole apparatus, does the ingenious American much credit*.

Perkins, now in the eighth year of his experiments, has lately stated that the difficulties which had heretofore retarded the introduction of his engine into practice have been surmounted. The tallow and other substances which he employed to lubricate his piston, and which were almost instantly converted into charcoal or volatilized, he can now dispense with altogether, by the invention of a metallic alloy for his piston, requiring no lubricating substance whatever. He joins his pipes by means of a short piece of metal, resembling frustrums of two cones united at their bases, with their apexes inserted into the pipes, in the manner practised when joining a series of wooden water-pipes: the flanges of the pipes are connected by bolts and regulating screws; this gives a great facility in making and keeping them steam-tight. Perkins has applied his peculiar improvements to some engines, and the value of his invention will be thus, it is hoped, speedily estimated in public opinion; his own is, that, by his mechanism, the same power is produced by half a measure of coals, as by a whole measure with those on the common construction. He is an experimenter of no common cast, and we anticipate much from his known ingenuity and unconquerable perseverance.

In this list of projects may be included the scheme of steam-artillery and steam-muskets. Mr. Watt tried something of that kind, but this

* A detailed account of this machine, with good figures, is given in Hebbr's *Register of Arts*, vol. v. p. 33.

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man of peace did not proceed far with the warlike project. Jonathan Hornblower also constructed what he called a steam-rocket; and the French general, Chasseloup, proposed, some few years later, (in 1805,) a similar plan for the defence of besieged places. M. Gerard, a French officer of engineers, is stated by Montgery to have carried this idea in practice in 1814, for the purpose of defending Paris at the approach of the allies. The boiler was moved on a carriage, and supplied steam for propelling balls from six gun-barrels, the breeches of which could be opened at pleasure; on turning a handle, the six guns received each a ball, and the steam at the same time—by a mechanism like what is seen in magazine air guns. The longest shots were made by turning the handle slowly, and one hundred and eighty balls were thrown in a minute; a waggon attended the machine to supply fuel and bullets. The capitulation of Paris prevented this novel artillery from being brought into action; and shortly afterwards the apparatus was taken to pieces. A similar invention was the subject of an American patent (in 1819); and the effects were described to be almost equal to those produced by the agency of gunpowder. The most recent attempt in the same way is that of Mr. Perkins; and it might, indeed, be considered to be almost exclusively in the line of his style of daring experiments. The sounds produced by his steam-guns were compared to a rapid running fire of musketry, accompanied with a rustling sound or roar, that quite deafened the unaccustomed ear. In his experiments before the Duke of Wellington, and a numerous party of engineer officers, the balls, at first, were discharged at short intervals, in imitation of artillery firing against an iron target, at the distance of

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thirty-five yards, and such was the intensity of the propelling force, that they were completely shattered to atoms. In the next trial the balls were fired at a framing of wood, and they actually passed through eleven planks, each one inch thick, of the hardest deal, placed at a distance of an inch from each other. Balls, also, which were fired against an iron plate, one-fourth of an inch thick, passed easily through it; on all hands this was declared to be the utmost force that gunpowder could effect; yet the pressure of steam required to produce this Perkins estimated not much to exceed sixty-five atmospheres, or nine hundred pounds on each square inch. To demonstrate the rapidity with which musket-balls might be thrown, he screwed on to a gun-barrel a tube filled with balls, which falling down by their own gravity into the barrel, were projected one by one with such extraordinary velocity as to demonstrate, that by means of a succession of tubes filled with balls, fixed in a wheel, a model of which was exhibited, nearly one thousand balls per minute might be discharged. The next experiments were of a more interesting kind, and appear to have been made as much with a view of destroying a *bull*, as of demolishing a target; and this, no doubt, in compliment to his Grace, who is so great an honour to the Emerald Isle. To the gun-barrel was attached a *moveable joint*, a lateral direction was then given to it, and the balls perforated a lineal series of holes in a plank nearly twelve feet long. Thus had the musket or gun been opposed to the regiment in line, it might have been made to act from one extremity of the alignment to the other. A similar plank was then placed perpendicularly, and in like manner there was a string of shot holes from one end to the other; and it was thus

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demonstrated that *steam-guns* could be easily made to *shoot round a corner!* In fact, it was doubtful whether they could not do the greatest execution in this way. The expense of this new mode of warfare was thus calculated by Perkins:—Suppose two hundred and fifty balls are discharged in a minute by the single-barrel gun, or fifteen thousand per hour; this for sixteen hours would require about fifteen thousand pounds weight of powder, which, at seventy shillings per hundred weight, would be five hundred and twenty-five pounds sterling. But the same number of balls can be thrown in succession, and in the same time, for the price of five bushels of coals per hour, or between three and four pounds sterling for sixteen hours!!!

After some experiments made at Greenwich, before Prince Polignac, and the French engineers who had been sent by the Duke d'Angouleme to make a report to him concerning them, Perkins received instructions to form a piece of ordnance to throw sixty balls of four pounds each in a minute, and this he guaranteed should be done with the correctness of a rifle musket, and to a proportionate distance. A musket will also be attached to the same generator for throwing a stream of lead from the bastion of a fort, and will be made so far portable, as to be capable of being moved from one bastion to another. Mr. Perkins states, from experiment, that he is within the truth when he estimates that with one pound weight of coals, he will do as much as with four pounds weight of gunpowder.

Perkins attributes his failure in engaging the English government to adopt this novel species of artillery to the "gratuitous and false statements of certain engineers, who declared, that though

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he could make a great display at a public exhibition, he had never made a generator which had stood for a week, and that he could not keep the steam up for more than two or three minutes at a time." To these *disingenuous opinions* Perkins opposes fact and experiment; and an engineer of great experience—a man of character and respectability, who witnessed the trials before the French engineers, has undertaken to make the engines, and to *guarantee* a saving of half the fuel used by one of the best condensing engines. An engine for a boat, with a nine inch cylinder, and a twenty inch stroke, the patentee and manufacturer guarantee shall be equal to the power of sixty horses: this stands in the sixth part of the space of a condensing engine.

In looking at Mr. Perkins's labours, the mass of prejudice with which he has been and continues to be assailed forcibly arrests attention: keeping the great value of his experiments totally out of view, his is no small share of merit for the steadiness of purpose with which he has borne up against the interests and spleen arrayed against him; for it cannot be concealed that his exertions have been spoken of in terms both contemptuous and harsh, although throughout they have been of that laudable and meritorious kind, that even failure in them should have brought him honour.

These prejudices, which cannot but have deeply injured the interests of a worthy, unassuming man, have yet had their origin in a circumstance highly complimentary to his talents and to his genius. At the announcement of his invention to heat water under an enormous pressure, the public was led, from statements which were neither sanctioned nor promulgated by the inventor, to indulge in the

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most extravagant speculations on the power and economy to be derived from his discovery. The disappointment of these absurd expectations was magnified into a reproach against the experimenter, although in fact Perkins performed all he had promised to do; and his scheme was only not completed from a practical difficulty in getting a suitable material for his generator,—an obstacle neither insuperable nor unforeseen.

One thing is certain, that viewing his exertions from first to last, no other mechanic of the day has done more to illustrate an obscure branch of philosophy by a series of difficult, dangerous, and expensive experiments—no one's labours have been more deserving of cheering encouragement, and no one has received less: even in their present state his experiments are opening new fields for philosophical research, and his mechanism bids fair to introduce a new style into the proportions, construction, and form of steam-machinery.

We will here collect a few schemes which have been thrown out, for machines acting by the agency of heat.

The first is M. Woisard's, for rendering variations of atmospheric temperature useful as a mechanical agent, by means somewhat different from those described in a former chapter; two vessels communicate by a vertical tube, and the lower one is immersed in water. The upper vessel, exposed to the action of the solar rays, incloses a balloon made of a flexible material; this is filled with air, and has also a small quantity of expansible liquid, such as ether, introduced within it.

As the atmospheric temperature falls, the bal-

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loon will diminish in bulk; the air surrounding it will become rarer, and the water will introduce itself into the machine through a valve; and when the temperature again rises, the pressure exerted within the machine, by the increasing volume of the balloon, will cause the excess of water to flow out. M. Woisard calculated, that if sulphuric ether was employed, and the machine of proper dimensions, it would raise to the height of one metre, as many times five hundred litres as there are cubic metres in the capacity of the outer vessel, whenever the temperature varies from fifty-nine to seventy-seven degrees Fahrenheit.

Mr. Samuel Morey, an American gentleman, produced a vacuum in the cylinder by firing an explosive mixture of atmospheric air and vapours, from common proof spirits, mixed with a small portion of spirits of turpentine. A working model was set in motion and kept at work, without elevating the temperature of the fluid from which the vapour is produced, to a higher degree than that of blood heat.

Mr. Montgery's turpentine explosive engine is an idea similar to Street's. Buchanan's capillary steam-engine is described as having had a generator made of a copper tube one hundred feet long and ¼ inch in diameter, and weighing about sixteen pounds. The cylinder was of sheet copper, three inches in diameter, twenty-seven inches stroke, and with all its appendages weighed twenty-five pounds; the whole engine when put together weighed one hundred and fifteen pounds. It was calculated for a four-horse power, but on trial exerted not more than the power of a single horse, because the generator was coiled up too compactly to admit the application of sufficient fuel, and the force pump did not

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supply sufficient water. This engine, it is said, afterwards worked a cotton manufactory at Nicholasville: it went forty double strokes in a minute, and the steam was cut off in the middle of its stroke: no safety-valve was necessary, there being no limit on the part of the generator to the strength to which it may be raised with perfect safety. The limit exists in the valves and joints, which cannot probably be made to resist more than three or four hundred pounds to the inch.

Galvanism has also been called in aid of navigation. The vessel to be propelled is to be converted under the flooring into one great galvanic trough, or furnished with a series of smaller ones, according as the one or the other may be proved most efficient in decomposing water, having also a receiver to contain the compound gas, which is known to be pure oxygen and hydrogen, in the proportion that forms water again when ignited. There is to be a cylinder open at the top, with a piston similar to that of an atmospheric engine; also a condensing vessel immersed in cold water. The cylinder is to have a communication, at the lower end, with both the receiver and the condensing vessel, with a valve to each. The vessel to have a narrow platform on *each side*, with a row of paddles on *each side* in a perpendicular position. The galvanic troughs were to be charged with sea water, to save the expense of acid. "We shall," says its author, "suppose it in action, and the receiver filled with gas; let the gas open into the cylinder, the gas will enter, and raise the piston, which is so connected with the paddles as to move them forward, which done, shut this valve, and open that into the condensing vessel, where the gas is to be ignited; a vacuum will then be produced under the piston, which will be forced down by

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the pressure of the atmosphere, causing the paddles to expand and move backwards*."

A like thought had, at the same moment, occurred to Mr. Thomas Hodgskin†; and as some points are much better explained in his description than in the preceding extract from the *Glasgow Mechanics' Magazine*, we will give his illustrations in his own words. "The great principle," he says, "is the application of voltaic electricity to the purposes of producing mechanic power. There is an instrument which produces, by the continued production of electricity, a perpetual, though not an equable motion. This principle has only been hitherto applied to make mere toys: but the voltaic battery, the most powerful instrument with which science has yet armed the hand of man, presents continual renewal of the electric current.—Why cannot we apply this instrument to produce a perpetual mechanic power?

"In Brown's pneumatic engine, the source of the power consists in burning hydrogen gas in atmospheric air. Brown found it very difficult to get rid of the nitrogen: but if we decompose water, by means of galvanic electricity, we can produce abundance of oxygen and hydrogen in those exact proportions in which they combine; and when flame or the electric spark is applied, they will condense into each other, and produce the most perfect vacuum which the art of man can form. A new power, hitherto never thought of, never put to any use, may be generated by decomposing water by means of galvanic electricity,

* Glasgow Mechanics' Mag. vol. I. p. 210.

† See the *Chemist*, a weekly periodical, edited by this gentleman, vol. II. p. 141, Lond. 1825.

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and re-composing the resulting gases by means either of flame, or the electric spark. By this means we generate a power, (the two gases,) in the first place equal to an additional atmosphere; and when we have thus generated this atmosphere, we may form a perfect vacuum by inflaming and condensing the gases. We have thus a first power equal to the atmosphere, which Brown does not produce, and after that we have the power derived from a far more perfect vacuum than he can possibly form; for the volume of the gases is diminished nearly two thousand times. Thus by a continued production of electricity, which is generated by a voltaic battery, we may go on for ever decomposing and recomposing to the end of the world, an enormous power with apparently inadequate means.

"The objections," continues Mr. Hodgskin, "to this apparatus amount in substance to two, The first is, that the expense of generating a sufficiency of the two gases will be so great in proportion to the quantity obtained, that it can never be so economic a power as steam. The value of this objection amounts to this,—that coals are now comparatively cheap in England, and copper, zinc, and sulphuric acid are comparatively dear: but there are countries differently situated. But those who make this objection are quite in the dark as to the quantity of the gases generated by a voltaic battery. No experiments, in fact, have ever been made to ascertain what quantity of gases are produced with a given voltaic battery within a given time.

"The expense of a voltaic battery containing ten pair of plates, each plate containing four square superficial inches, is about forty-four shillings: four hundred pair of plates will, therefore, cost

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eighty-eight pounds; with the ordinary wear and tear of such a battery, it will last about two years. Let us suppose that ours will be more frequently in action, and will last for one year. The troughs, which want no renewing, cost ten shillings; and the acid employed costs three pence a pound weight. The proportion recommended is one pound weight of acid to sixty pounds weight of water; and supposing that the acid requires renewing every day, we shall have, for the daily expense of this substance, three shillings and four pence. The labour of managing this part of the business will be a mere trifle,—so that for a capital of eighty-eight pounds, and an annual charge of sixty pounds, we may get a very considerable power; the cost of its application is another thing, and must be decided upon other principles. In our opinion, it is a considerable recommendation of the voltaic mechanic power, that all the materials which go to produce it are, in a great measure, the product of labour, and will get cheap as that labour is made more efficient: another thing, also, which requires to be observed is, that the copper and zinc and the acid employed would not be annihilated and might be recovered; consequently the expense of supplying these articles will be little more than the expense necessary to recover them after being used. Thus the power actually employed is only that immaterial agent which is made manifest on the decomposition and recomposition, and which, as it is measureless, is inexhaustible. If, therefore, the suggestion may be of great utility, where fuel is dear, or where it cannot be procured even where it is cheap, a voltaic mechanic power may still have some recommendations. The space into which it may be put is small; it emits no smell,

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and sends forth no smoke; it will annoy nobody, and never be a nuisance; it does not depend for its operations on the elements; the materials for its production are all easy of carriage, and may thus serve to equalize the gifts of nature, and liberate industry from the fetters of local restriction."

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CHAPTER THIRTY-ONE.

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It may be asked what security have we, that we shall be able to retain this branch of manufacture, now that other countries, over which we possess no exclusive natural advantage, are using efforts to participate in its benefits? these rest upon our persevering industry, our economy, and our great capital. The start we have got of our competitors in the career of invention and discovery is another important advantage, for invention is progressive, every discovery that is made having the effect to unfold principles leading to other discoveries, or to analogous applications; and, when the manufacturing class has once received this impulse, those who conduct the processes, and those employed in the operative part of them, have their thoughts constantly turned to the means of enlarging the powers of the machines they are in possession of, or to the discovery of other machines for executing work still performed by hand—there is a progress also of art in the use of that machinery, of contrivance to supply its defects, and of little, undefinable, subsidiary aids for the furtherance of the work, which contribute to give a superiority to it over every undertaking of a more recent date.

Dugald Bannatyne.

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CHRONOLOGICAL LIST OF PATENTS.

WHICH HAVE BEEN GRANTED FOR IMPROVEMENTS MADE ON STEAM-ENGINES, ON FURNACES, ON BOILERS, ON THE MACHINERY OF STEAM-BOATS, AND LOCOMOTIVE CARRIAGES.

Some facts and observations, which could not be introduced into the narrative without confusing it, are here interspersed in their chronological order; and a few have been inserted as corrections which have occurred to the author during the progress of his work through the press. Those persons whose names are printed in ROMAN CAPITALS, have received patents for their inventions in the year under which their names are placed; that part of the machinery to which their improvement relates is generally indicated, and of some schemes a brief analysis has been attempted. But it will be obvious that in a list of this kind, these sketches must be very limited as to number, and detail, from the requisite information being inaccessible. For it may with perfect truth be asserted, that until the commencement of the "*Repertory of Arts*," by Mr. Wyatt, ninety-nine out of every hundred patents which had been granted, were unknown to any except their authors. "*The Technical Repository*," edited by

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Mr. Gill, and the "*London Journal of Science*," edited by Mr. Newton, have followed the same path. These excellent and useful monthly publications have made the Patent-Office, which previously to their appearance had been a pool of oblivion, become in practice (what it always was in theory) a fountain whence the experience and inventions of ingenious individuals flow throughout the community. In the pages of these journals will be found detailed descriptions and numerous engravings of many inventions connected with steam-engine machinery, of which, from the plan of our work, a catalogue only could be given. To these works may be added three others of more recent origin. "*The Mechanics' Magazine*," "*Heber's Register of Inventions*," and the "*New London Mechanics' Magazine*," (all published weekly.) The last named, although it gives accounts of the more important inventions, is not so exclusively mechanical as the two former. "*The Mechanics Magazine*," embracing a great range of subjects, is necessarily brief in its descriptions; and in the department of Patent Inventions especially it is less copious than "*Heber's Register*," which is devoted almost exclusively to this class of subjects. "*The Monthly Magazine*," from its commencement, gave popular analyses of patents without figures; and "*The New Monthly Magazine*" follows the same plan. "*The Philosophical Magazine*," especially the earlier volumes, contains descriptive notices of many inventions; when engraved illustrations were given they were sometimes beautiful. And "*Nicholson's Journal*," so long as it was conducted by its first editor, also noticed many patent mechanical inventions. To these books we refer those in search of detailed information on many of the subjects contained in this chapter, and throughout our book generally. To have acknowledged the obligation in every instance in which we availed ourselves of their stores, might have been considered an affectation both of industry and gratitude, in a work like this which is professedly a compilation.

1630.

DAVID RAMSEYE, groom of the privy-chamber to Charles the First, had a patent for inventions "to raise water from low pits by fire—to make any sort of mills go on standing-waters, by continual motion, without the help of wind, water, or horse; and to raise water from low places, and mines, and coal-pits by a new way never yet in use." These apparently are all variations of the same scheme.

In addition to the notice given of Decaus, p. 27, may be added, that, "he was a native of Normandy. When he left the service of the Prince of

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Wales, he went to Bavaria as engineer to the Elector. He published a book on *Le Perspective avec la raison des ombres et miroirs*. Lond. 1612. *Le raisons des forces mouvantes*. Francfort, 1615; reprinted at Paris, 1624. The translation of this into German ran through several editions; the third part, treating of organs, is very remarkable. *Hortus Palatinus*. Francfort, 1620, with figures by de Bry, of the embellishments he formed in the Elector's gardens at Heidelberg. *Institution Harmonique*. Francfort, 1615, dedicated to Anne Queen of England. *La Pratique et le Demonstration des horloges Solaires*. Paris, 1624; all these works are in folio, and of great rarity. He died in France about 1630." —*Roquefort*.

1698.

THOMAS SAVERY, London, raising water by the direct pressure of steam on its surface, and condensing the vapour which had expelled it, the air's weight forced an equivalent column of water into the empty receiver.

"It does not appear," says Mr. Watt, "that the Marquis of Worcester knew anything of the use of an injection, as the machine described by him operated only by the expansive force of steam; whereas the injection was used in Savery's engine from the beginning, and is, in all probability, his invention."—*Robison's Mec. Phil.* vol. ii. p. 50. "The venerable improver of the steam-engine may have been writing from recollection when he stated this opinion. Condensation was produced in all Savery's engines by cold water thrown on the outside of the receivers. In an engine erected by Savery himself in 1710, the injection was not used; and, in the *Miner's Friend*, there is no mention of any contrivance like it."

1705.

THOMAS NEWCOMEN, and JOHN CAWLEY, (or Calley,) Dartmouth; and THOMAS SAVERY, London, admitting steam under a piston attached to a lever—condensing the vapour, a weight is raised by the atmosphere pressing the piston downwards.

HENRY BRIGHTON is said to have had a patent for an improvement on the mechanism called a hand-gear, for opening and shutting the valves—and JOHN POTTER for some improvements on the valves and boiler, but the date has not been given.

Charles Prince of Hesse visited England and inspected Savery's engine; and had its action explained to him several times by the inventor. The prince wished Savery to accompany him to Cassel. In 1706, a gentleman from the Prince of Hesse requested Savery's assistance to alter a model of an engine on Papin's plan, which could not be made to act. Savery made the necessary alterations upon it. In

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the fac similes of handwriting, that given is the autograph of William Landgrave of Hesse, the father of Prince Charles—they were both excellent mechanics and patrons of Papin.

1710.

NEWCOMEN and CALLEY erected their first effective engine; and Savery erected an engine at York-Buildings Water-Works; but whether as an experiment, or at the expense of the company, is not known.

1714.

A fire-engine, erected, at a mine, near Austhorpe, Yorkshire. The patentees agreed to work and keep the engine in order for two hundred and fifty pounds a year: during the four years it was in operation they burned out four boilers. The cylinder, according to Smeaton, who derived his information from an old man who had attended the engine, was twenty-three inches in diameter, and had a six feet stroke; it made fifteen strokes each minute when worked by hand; twelve when moved by handgear. Calley superintended its erection. Only three others were in existence—two of these were at Newcastle—the third, at Coventry, had no working gear, but the cocks were moved by hand.

1716.

SIR MARTIN TRIEWALD was a Swede, who came to England in 1716, to obtain information regarding the mode of mining followed at Newcastle—he remained in that neighbourhood for some years, and was employed as an engineer at a coal-mine; he was a pupil of Desaguliers, and some of his improvements on the diving-bell are described in the Doctor's Experimental Philosophy. He returned to Sweden in 1726, and erected an atmospheric-engine, the parts of which he got fabricated in England. He was captain of mechanics, and military architect to the King of Sweden; and was in correspondence with some of his friends in the Royal Society until his death. He invented a mode of warming conservatories by *hot water*.

1717.

MR. JOHN CALLEY, one of the great improvers of the steam-engine, died this year at Austhorpe in Yorkshire.

"MR. BEIGHTON'S account of an experiment which he made on the fire-engine, to know what quantity of steam a cubical inch of water produces.

"I found by several experiments by a divided steelyard, on the puppet or safety-valve of the boilers, at Griff and Wasington, that when the elasticity of steam was just one pound avoirdupois on a square inch, it was sufficient to work the engine, and that about five pints in a minute would feed the boiler, as fast as it consumed in boiling, and

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steam for the cylinder sixteen strokes in a minute. The Griff cylinder held one hundred and thirteen gallons of steam, every stroke in a minute equal to 1808 ale gallons—*so five* pints of water produced 1808 gallons of steam, 38·2 cubic inches in one pint—then 38·2 inches : 1808 gallons : : 1 inch : 47.3 gallons—hence it appears one cubic inch of water, by boiling till its elasticity is capable of overcoming about 1-15 of the atmosphere, will make 13338 cubic inches of steam.

"By experiment I have found that from the eduction valve of a thirty-two inch cylinder, there comes out one gallon each stroke. It is surprising how that *steam, which is made of about three cubic inches of water, should heat one gallon of cold water so as to have it come out scalding hot*, which it does, and the cylinder in all its upper part is *but warm* when the piston is down."—*Desaguliers' Exper. Phil.* vol. ii. p. 533.

The mistake in the calculation which gave 13338 cubic inches of steam, instead of only 2893, has been noticed by many authors, from Smeaton downwards. The great heat imparted to cold water, by a small quantity in the form of steam, was a fact which could not be explained until the discoveries of Doctor Black, nearly forty years after this period.

Newcomen's way of finding the power of the atmospheric engine was this. "From the diameter squared he cut off the last figure, calling the figure on the left hand long hundreds, and writing a cypher on the right hand called the number on that side pounds; and this he reckoned pretty exact at a mean. Or rather when the barometer stood at thirty and the air was heavy—this makes between eleven and twelve pounds upon every superficial round inch—then he allowed between one third and one fourth part for what is lost in the friction of the several parts and for accident, and this will agree pretty well with the work at Griff engine; there being lifted at every stroke between two-thirds and three-fourths of the weight of the atmospherical column pressing on the piston.

"This engine at a coal mine at Griff, from whence the draught was taken, did discharge as much water as did before employ more than fifty horses, at an expense not less than 900*l.* a year. Whereas the fire, in coals, attendance, and repairs, did never cost more than 150*l.* a year in this engine."—*Desaguliers' Exper. Phil.* vol. ii. p. 482.

Beighton supplies water to the boiler from the eduction pipe of the cylinder, instead of using that which had lain on the top of the piston.

1723.

POTTER, an Englishman, erects a steam-engine at a mine at Koningsberg in Hungary—the mode he employed to open the

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steam-cocks is shown in the engraving. The cylinder was thirty inches in diameter. He was long afterwards considered in Germany to be the inventor of the engine itself, in consequence of Leupold's assigning him that honour in his Theatrum Machinarum.

1725.

NEWCOMEN'S engine generally employed to drain the collieries at Newcastle.

Andrew Wauchope of Edmonstone, Mid Lothian, obtains a license from the committee in London appointed by the proprietors of the patent for the engine for raising water by fire. The engine he is to erect at his own cost is to be after the manner of that used at the Elphinstone coal-work—the steam cylinder is not to exceed nine feet in length, and twenty-eight inches in diameter—Mr. Wauchope engages to pay 80*l.* a year for eight years for this licence. The committee agree to provide the *cylinder*, *regulator*, and *other* brass-work, at the cost of the proprietor. The workmen who erected it were all from *somewhere beyond London*.

Mr. Bald has given the following account of the cost of the particular parts of this engine:

	£	s.	d.
A cylinder 20 in. in diameter with workmanship, carriage to London, and all other charges . . .	250	0	0
A piston . . .	9	10	0
A brass barrel 7 ft. long	17	10	0
A brass bucket and clack	0	13	0
Paid for elm pump pipes at London	53	4	6
Two cast metal barrels 9 ft. long 9 ft. diameter, and expenses connected with them	41	16	0
Two brass buckets and two clacks, 9 in. diameter; a brass regulator and injection cock, and other cocks, sinking-vouls, injection caps, snuffing vouls, and feeding vouls . . .	35	5	0
One jack for the wy	0	12	0
Plates and rivet iron, for making the boiler . .	75	10	0
Six Swedish iron plates	6	3	0
Plumber's bill for lead, and a lead top for the boiler, with sheet lead, and lead pipes .	78	10	6
Solder	15	10	0
Timber, bought in Yorkshire, for the engine, with carriage by land and water and freight to Newcastle	82	16	
44 cwt. 1 qr. 14 lbs. of chains, screw-work, and all other iron work about the engine, except the hoops			

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of the pumps, at 5*d.* per pound .	103	10	10
Ropes	19	16	0
Cast-metal bars for the furnace . .	16	14	0
A hand-screw . .	1	17	0
Two brass codds for the regulator beam . . .	5	14	0
Plank for the plug-holes in the pumps	2	10	6
Leather	18	13	0
Iron hoops for the pumps, with screw-bolts and plates for do., 18 cwt. at 4*d.* per pound . . .	32	12	0
Two copper pipes	0	8	0
Carriage of the materials, from London and Newcastle to Scotland	22	2	0
John Potter, pains of going and coming upon account of Edmonstone engine .	50	0	0
Travelling expenses of the workmen, and their wages	52	18	0

Six workmen were sent from England—they had 15*s.* a week as wages, besides their expenses paid.

John and Abraham Potter, of the bishopric of Durham, were the engineers. They engaged to make it an efficient engine to draw water by pumps of seven and nine inches bore. The engine exerted between seven and eleven horse power. All the expenses of erection were to be paid in the first instance by the engineers—to be repaid with a premium of 10 per cent. out of the price and profit of the first coals that should be raised by it. Abraham Potter was to be paid 200*l.* a year for his pains, and for keeping workmen to attend the engine, and for wear and tear in repairing. He was to be furnished with coals gratis, and be allowed a reasonable time for repairs—and the expenses of any accident that might happen to the engine were to be taken from the profits of the mine—after the first cost of the engine the annual expense of coals to work it and the repairs and salary to the engineers—the engineers were to have half of the remaining profit of the coal mine—with a stipulation that, if the engine was not capable of draining the mine, the engineers might take away all the materials furnished by them, with a reasonable allowance for their labour and expenses.

Some of these stipulations will lead to the inference that the mine had previously been of small value to the proprietor, and that he entered into the bargain upon the principle that even a very small gain was better than none at all. The licence, indeed, commences by stating that the Edmonstone colliery could not be wrought in consequence of the increase of water.

The patent under which the license was granted is not

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known—Did Newcomen and Calley obtain a renewal of their exclusive privilege?

1726.

April—A steam-engine used at York-Buildings, London, for raising water; it consumed two chaldrons of coals in twenty-four hours, and raised fifty tons of water per hour.

1731.

The *Evening Post*, of Sep. 16, 1731, says, "We hear that the York-Buildings Company have given over working their fire-engine; and that the houses which were formerly supplied with water from the reservoir at Marylebone will be no longer supplied from thence—great numbers of the inhabitants having already applied themselves to the collectors belonging to the Chelsea Water-Works, in order to be served with water from the reservoirs in St. James's and Hyde-Parks, who have new laid their pipes accordingly. We also hear that the mud, which formerly lodged in the canals belonging to the said water-works, is washed out, and that the same are now constantly kept clean by means of a back-water contrived for that purpose, except a ridge of mud, which is purposely left in the middle of the great canal, which divides it into two canals, which are found more convenient than when it lay all in one." The engine named is probably one on Savery's construction.

1732.

Motraye gives a view of the York-Buildings Water Works. Savery's engine is represented standing beside Newcomen's. Mortraye mentions three engines; one is placed between the water-engine of London Bridge, another towards Chelsea, and the third towards Islington; the first is said to have the appearance of a column or tower.

1736.

Jonathan Hulls' first patent for a boat impelled by wheels, moved by Newcomen's engine. Hulls was a native of Exeter. The following extract is made from the *Edinburgh Encyclopedia*, published while this sheet was passing through the press: "Mr. Robert Stuart, in his excellent *Descriptive History of the Steam-Engine*, page 33, London, 1824, seems to us to have committed a very serious mistake, in ascribing the invention of the crank to Jonathan Hulls, and thus depriving Mr. Watt of the honour of an invention which he had considered so completely his own as to secure it by a patent. In this scheme (meaning Hulls,) says Mr. Stuart, '*it was necessary to* convert the alternate rectilineal motion of a piston rod into a continuous rotary one, and which he ingeniously suggested might be accomplished by means of a crank. This is

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now with justice considered to be that invention, which introduced the steam-engine as a first mover of every variety of machinery. Hulls was unable to interest the public in his project, and his mode of applying the crank was so completely forgotten that, at its revival, about forty years after this period, a patent was obtained for the invention, and the merit of the application was also claimed by the celebrated Mr. Watt, evidently without any knowledge of Hulls' suggestion.' In Hulls' method the rotary motion was effected by ropes and wheels, as will be seen in the drawing which will be given under our article *Steam-Boat*, and no crank is ever mentioned. It is true that Hulls afterwards says, 'up upland rivers, where the bottom can possibly be reached, the fans may be taken out, and the cranks placed at the hindmost axis, to strike a shaft to the bottom of the river, which will drive the vessel forward with the greater force;' but this cannot, by any stretch of criticism, be considered as the conversion of a reciprocating into a rotary motion, by means of a crank. Had Hulls once got hold of the idea, of applying the crank in this way, he would never have adopted the other contrivance, the exposure of which to the injury of the sea he obviously considers as an objection. Mr. Watt must, therefore, be allowed the great merit of the application of the crank, to convert the vertical motion of the piston into a continued rotatory motion."—*Edinburgh Encyclopedia*, vol. xviii. p. 364.

"The substitution of the power of horses, or of steam, or of heated air, in place of the strength of men, appears to us no invention at all; if it were, we should have numerous rivals contending for the honour of applying the steam-engine to the threshing machine. When Mr. Jonathan Hulls therefore, in the year 1736, took out a patent for the application of one of Newcomen's steam-engines to a vessel for towing ships in and out of harbour, he merely proposed to substitute the power of steam in the place of the power of men: his proposal was neither characterised by sagacity nor inventive genius; and the intermediate mechanism, by which the reciprocating motion of the piston was converted into the rotary motion of the paddle-wheels, or fans as he called them, was clumsy and imperfect."—*Brewster*, in *Ferg. Mechanics*, vol. ii. p. 113. In anticipating a similar objection, Hulls gives a fair answer to it: "If it should be said that this is not a new invention, because I make use of the same power to drive my machine that others have made use of to drive theirs for other purposes, I answer, the application of this power is no more than the application of

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any common or known instrument, used in mechanism for new invented purposes."—*Hulls.* "It is not always a fair way to judge of the value of a contrivance by its importance, as estimated in times of comparatively refined invention.—At this moment, 1824, we should call the application of the steam-engine to move balloons, a very fine invention, although the engine itself should be the identical one that had moved a threshing machine or a coal-waggon."—*Stuart's Des. History*, p. 84.

In the article Ship-Building, in the *Edinburgh Encyclopedia*, Hulls' project is mentioned. "This important and original thought was, however, never carried into practical execution by Hulls, probably from the want of funds, and sufficient encouragement."—vol. xviii. p. 216.

BERNARD BELIDOR, a French engineer, describes a steam-engine erected at Fresnes.

1741.

PARLIAMENT granted a drawback of all the duty on coals used for steam-engines employed in the Cornish tin and copper mines.

1752.

NEWCOMEN'S engine, first applied by Champion, near Bristol, to pump up water to supply a water-wheel.

"In the year 1757, Mr. Keane Fitzgerald communicated to the Royal Society of London a paper, entitled, An Attempt to improve the Manner of working the Ventilator by the help of a Fire-engine. As the lever of the fire-engine works up and down alternately, and performs, at a common medium, about a dozen strokes in a minute, it was necessary to contrive some way to make the beam, though moving alternately, to turn a wheel constantly round one way, and also to increase the number of strokes to fifty or sixty in a minute. Dr. Robison had, without due consideration, regarded this contrivance of Mr. Fitzgerald as involving the invention of a crank, with which Mr. Watt had afterwards converted the vertical motion of the piston into a rotary motion, and had, therefore, deprived Mr. Watt of that honour. Mr. Watt, who, as it will afterwards be seen, had been particularly harassed regarding the subject of the crank, corrected to a certain degree this error in his annotations on Dr. Robison's paper; but in a letter which he wrote to Dr. Brewster, (February 23, 1814,) he speaks still more decidedly—'Dr. Robison,' says he, 'mentions, that Mr. Keane Fitzgerald published in the Transactions a method of converting the reciprocating motion of the steam-engine into a continued rotary motion, by means of a crank or a train of wheel work, and

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adds, "by this contrivance he hoped to render it of most extensive use; and that he, and others associated with him, obtained a patent for it; they also published proposals for erecting mills of all kinds driven by steam-engines, and stated fairly their powers, and their advantages."

"'Now I find,' continues Mr. Watt, 'that in the *Philosophical Transactions*, there is an invention by Mr. Fitzgerald, for working ventilators by means of a steam-engine, in which the rotative motion is produced by a train of wheel-work, which *ultimately turns a crank*, which works the ventilators, *a very different thing from rotary motion produced by the intervention of a crank.* As to the mill scheme, we can find no trace of it, nor of the patent, and being a matter of some consequence to clear up, I have written to some friends in London about it, but have as yet received no answer. I shall thank you, if you cannot otherwise find out the matter of fact, to get a search made among Dr. Robison's memoranda, to learn upon what authority he made the assertion. If nothing more is learned about it, I must conclude the note to be a mistake, and comment upon it accordingly—no record of a patent was found at the public offices, and Mr. Watt accordingly made those alterations on Dr. Robison's papers which are already before the public.' It is impossible to pass over this statement, respecting the crank, without calling the attention of the reader to the annoyances to which an inventor is exposed, by the rash decisions and criticisms of his friends. If Dr. Robison and Mr. Stuart, men of talents and character, and great admirers of Mr. Watt, have, under a sense of justice, attributed one of his finest inventions, the one to Mr. Fitzgerald, and the other to Jonathan Hulls, without any other foundation than the recommendation of a crank as part of the machinery, it is not to be wondered at that writers of inferior judgment and integrity should so often commit the same mistake. To this species of persecution Mr. Watt has been particularly exposed; and yet the whole history of science does not present to us an individual whose inventions were more original, and to which less approach had been made by the ingenuity of his predecessors."—*Ency. art. Steam Engine*, vol. xviii. p. 365.

These passages concerning Keane Fitzgerald, and that relating to Jonathan Hulls, containing charges against himself, Mr. Stuart quotes at length, as a penance, and he pleads guilty to the charge of "a rash decision on Hulls' invention." It may, however, be a slight extenuation of his offence, that *The Descriptive History of the Steam-Engine*, in which that

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opinion was hazarded, was a first performance. The subject also on which it treated was new to the public, and many of the sources from which he could have corrected the scanty information found in other authors, if not unknown, were then inaccessible to him. The unexampled success of this Descriptive History, as a literary speculation, put several opportunities in the author's power, for correcting both facts and their inferences. But these opportunities were lost, from the circumstance of the first edition being printed from *stereotypes*, which were used in all the subsequent impressions. The bankruptcy of the booksellers, who published the three first editions, having made these stereoplates become the property of more respectable parties—there is now some chance of their errors being corrected.

These *Anecdotes of Steam-Engines* may, however, be considered as an extension of the author's design (sketched in his *Descriptive History*) of giving a *popular* view of the progress towards perfection of the beautiful combinations exhibited in steam-engine machinery. Many of the hasty opinions in his first work the author hopes will be found corrected in this. And it affords him some pleasure that the cases quoted above from the *Edinburgh Encyclopedia, were corrected in those portions of the Anecdotes of Steam-Engines which were published at least twelve months before the* appearance of the volume of the Encyclopedia containing the animadversions referred to.

1754.

EMERSON gives some rules for estimating the power of the atmospheric engine. His laboured approximation was no nearer the truth, than that had by the short empirical rule of Newcomen.—Twenty years after this period he extended his problem further—but without making it of the least use to practical men.

1759.

JAMES BRINDLEY, engineer to the Duke of Bridgewater, improvements on boilers.

"Newcastle, February 26, 1763. Landed at Winkham Lee Coal Staith, for the use of the Walker Colliery, a fire-engine cylinder, the largest that has ever been seen in this country or perhaps in any other; 10½ feet long: the bore measures 74 inches, weighs, exclusive of bottoms and piston, 130 cwt. or 6½ tons, together with piston and bottom contains between 10 and 11 tons of metal. The bore is turned perfectly round and well polished, and the whole is so complete and noble a piece of iron work, that it does the greatest honour to the place where it was cast—Coalbrook Dale, Salop. When the engine is finished, it will

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have the force to raise at a stroke 307 cwts. of water."

1762.

JOHN OXLEY constructed an engine at a mine near Seaton Delaval, to turn a machine with a continuous circular motion derived directly from the great lever—it worked some years, and was given up.

Hindley of York, a clock-maker, made an engine for the water-works of Kingston upon Hull. It worked without a great lever; the pump was placed beneath the cylinder; the piston rod of the engine was connected to that of the pump by a frame which moved up and down like a sash window; the atmosphere pressed down the piston.—Hindley intended to have made the steam press the piston upwards, to get rid of the counterweight; but he died while the engine was in progress.—Smeaton afterwards altered this engine to his own model.

By his theory of latent heat, Dr. Black explains the fact noticed by Beighton, of the great quantity of heat in steam; and which was also at this time observed by Watt.

1766.

JOHN BLAKEY, London, an improvement on Savery's engine.

An engine on Savery's plan, erected for some salt works at Castiglione, near Grosseto, a town in Tuscany, by Cambray de Rigny. Great care was bestowed by Cambray in adjusting the proportions of its parts; and he added various ingenious methods for opening and shutting the valves, so as to render the mechanism nearly a self-regulating one. De Cambray's experiments, which were published, are more valuable than any that had been made on the engine. The machine cost 50,000 livres. The expenses "*d'administration*" are thus stated:

	livres.
Wages "d'un Maître Machiniste" for a year	1200
Three "Maîtres au fourneau," night and day for six months . . .	1400
"Trois manœuvres," for the same time . . .	800
Wood "pour l'entretien du feu"	1800
Carriage, repairs, and accidents	2800
	8000

1769.

DUGALD CLARKE, London, continuous from a reciprocating motion. He erected an engine at London.

JAMES WATT, Glasgow,—excluding atmosphere from cylinder—keeping cylinder as hot as the steam—condensation produced in separate vessels—air extracted from condenser by pumps—pistons pressed by the steam—a steam-wheel—partial condensation of steam—using oil and wax instead of water: January 5, 1769.

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1770.

About eighteen large engines at work in Cornwall, exerting a power equal to that of 490 horses.

1771.

J. Chrysel, London: construction of furnace—this was applied to the manufacture of salt: he published a short pamphlet detailing some of its advantages.

1774.

Jonathan Greenal, of Parr, Lancashire: Fire-engine for draining mines, coal-pits, and lands of water.

1775.

A list of the weights and prices of some of the parts made of cast iron of the Chacewater engine manufactured at Carron.

Weights.

Cylinder, bored through 72 inches, diameter 10·5 feet long, flayed at its ends and in the middle for the purpose of fastening it to the beams—4 tons, 16 cwt. 4 lbs.

Hemispherical cylinder bottom, with its plunge; short steam-pipe; necks for injection pipe, snuffing pipe, and eduction pipe—1 ton, 13 cwt. 36 lbs.

Cup or circular to fix on top of cylinder—13 cwt.

Cast iron piston—14 cwt. 10 lbs.

Cast iron axis from working beam—16 cwt. 14 lbs.

Cast iron part of regulator or steam valve—1 cwt. 98 lbs.

See the engraving marked.

Prices of casting delivered in Cornwall.

Bored cylinders, working-barrels, regulator-valves—28*s.* per cwt.

Clock and buckets turned—21*s.* per cwt.

Cylinder bottom, piston, cup, clack door pieces for pumps—18*s.* per cwt.

Axis and similar castings—16*s.* per cwt.

Common pipes, for pumps; other plain pipe-work, furnace doors—14*s.* per cwt.

Grate bars, bearer bars, hearth plates, weights—11*s.* per cwt.

Wrought iron screw bolts and nuts—5*d.* per lb.

Brass castings for pump clack seats, regulator valve, injection cock—16*d.* per lb. without turning and fitting.

1776.

An atmospheric engine placed in a coal-mine, 480 feet below the surface, near Whitehaven. In 1778, another similar engine, having a cylinder 70 inches in diameter, was placed at the bottom of Yatestoop mine; 600 feet under the surface—another engine was placed at the surface from which the mine pump rod, or "dry-spear," descended to work a pump placed at the bottom; this was 600 *feet long!* The boiler flue was carried up in the mine shaft;

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the boiler was 20 feet in diameter, and the excavation in the rock in which it and the engine-house was erected cost 300*l*.

A LAKE near Rotterdam covering about 7000 acres, which had been embanked, was drained by 34 wind-mills. Van Liender, in 1776, erected a large atmospheric engine in aid of the mills; it had a cylinder 52 inches in diameter and 9 feet long—the iron work came from England—it was not very effective.

SMEATON erected an oil-mill at Hull—an atmospheric engine pumped the water on a wheel: after this the method may be considered as an established one for producing a continuous motion.

1777.

JOHN STEWART presents to the Royal Society a scheme to accomplish the same purpose as that of Clarke, in 1769. Two endless chains, revolving over pullies fixed in a frame, which rose and fell by the motion of the engine—joint-pins in the chains acted upon the teeth, at opposite sides of a wheel which received a circular motion, by one chain acting on one side, and the other chain acting on the other side alternately. Stewart says, "a *crank* or *winch*, although a mode of obtaining a circular motion, would in this case be inapplicable," for some reasons which were then considered to be unanswerable, but which experience has long since shewn to have been erroneous.

WATT erects one of his engines for blowing an iron furnace at Wilson House, Lancashire—this was the first application of the blowing cylinder for furnaces.

1778.

BOLTON computed the expenditure of fuel in his engine at this time, thus:—

The space in the cylinder moved through by the piston in cubic feet, multiplied by the load on each square inch of the piston in pounds, the product will be the number of pounds weight of coal consumed for every 1800 strokes of the engine—this is equal to an effect of 21·75 millions of pounds weight raised one foot by a bushel of coal.

BATAVIAN SOCIETY, at Rotterdam, offers a premium for a plan of an apparatus, to be annexed to a steam engine to make it capable of raising water to all heights under five feet.

1779.

MATTHEW WASBROUGH, Bristol, rotative from alternate rectilineal motion.

1780.

JAMES PICKARD, Birmingham, application of crank to steam-engines—Wasbrough and Pickard joined their interest.

Watt and Bolton send the parts of the engine at Chaillot to Paris.

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1781.

JONATHAN HORNBLOWER, Penryn,—two cylinders, steam leaving one enters the other—condensing by bringing the steam in contact with the metalline surfaces—discharges water by a pipe, equal in length to the column of water balanced by the atmosphere—air enters a separate vessel, from which it is expelled by the steam—separate vessel for condensing vapour—piston having steam round its periphery.

1781.

JAMES WATT, Birmingham, several methods for regulating motion. Sun and planet wheels.

M. D'ARNAL, at Nismes, works flour mills by two steam-engines—they pumped water into a reservoir to be conducted on ten small wheels each of which turned a mill-stone.

1782.

JAMES WATT, Birmingham, Double impulse engine. Expansive engine. Contrivances for regulating motion—two cylinders—rack and sector or great lever—semi-rotary engine—steam-wheel.

WATT and BOLTON erect one of their engines with a *crank* and *fly-wheel*, at Pimlico Wharf, for the Chelsea Water Works; and another, double impulse, at the Bradley Iron Works.

1783.

ARKWRIGHT builds a cotton-mill on Shude Hill, near Manchester; from an ill-judged economy he used an atmospheric-engine to pump up water on a wheel, to give motion to the machinery.

1784.

JAMES WATT, Birmingham, rotary engine. Parallel motions—mode of applying engine to move pumps, and mills, and lift hammers and stampers—mode of opening valves. Portable steam-engine, and steam-carriage.

WATT makes some experiments on the power of horses; he found that a strong horse, such as those used by London brewers, could draw a weight of 150 pounds avoirdupois, attached to a rope moving over a pulley, so as to raise it at the rate of 220 feet per minute—this is equal to 33000 pounds raised one foot, or 528 cubic feet of water. This he denominated a horse-power, and estimated the power of his engines accordingly.

Albion flour mills, London, began to be erected—the machinery to be moved solely by means of two of Watt's double impulse engines, having cylinders 34 inches in diameter. The justly-celebrated Rennie superintended the erection of the mill work, and Wyatt designed the building; the engines were of 50

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horse power each, driving 20 pair of mill-stones; the wheels, and axes, and other parts which previously had been formed of wood, were all of cast iron.

ROBERT CAMERON, London: Heliacal engine—improvement on Newcomen's.

1785.

JAMES WATT, of Birmingham. Furnaces for consuming smoke—These will be described in *Stuart's Practical Treatise on the construction of Steam-engines.*

BOLTON and WATT erect one of their double impulse engines for Messrs. Robinson, at Papplewick, Nottinghamshire—the first instance of the direct application of steam to this purpose.

A COLONY of mechanics, from Scotland, established in 1786, at St. Petersburg, by Mr. Gascoigne, who had the management of the practical department of the Carron works under Mr. Garbet. He was patronised by the Empress Catherine, and received a title of nobility. Steam-engines were fabricated here shortly afterwards.

1788.

MINT for copper coin set up at Soho—driven by Watt's engine.

1789.

THOMAS BURGESS, London: a rotative from a vibrating motion, by a rope from the working beam passing round a cylinder furnished with a ratchet wheel, &c.

1790.

BETTANCOURT publishes his experiments on steam.

WATT and BOLTON send an engine to Nantes: it was put together by workmen from Soho. The furnace consumed its smoke.

1791.

EARLY in the morning of the 3d of March, the Albion Mills were observed to be on fire. The entire edifice and stock of grain was destroyed; the premises were ensured for 26,000*l.* and the stock for 35,000*l.*: 4000 sacks of corn were consumed. It was considered to have been the act of an incendiary, who was never discovered—from its beginning strong prejudices existed against the establishment, in those classes who ultimately would have been the most benefited by its operation. This successful adaptation of the double condensing engine to grinding corn, decided the point as to its superiority over Newcomen's apparatus—from this time it began rapidly to supersede the rival mechanism.

JAMES SADLER, Oxford: steam-wheel.

1792.

WILLIAM SYMINGTON, Kinnard: condensing engine.

MR. SCOTT began spinning

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cotton by steam power at Glasgow — the manufactory was situated on the south bank of the river Clyde, directly opposite the Delft works, where Watt erected the first model of his condensing engine, before he applied for his patent.

1793.

FRANCIS THOMPSON, London: atmospheric engine—two cylinders.

BENJAMIN GOTT erects a woollen manufactory at Leeds —its machinery driven by a 40 horse power condensing engine. This was the first manufactory of the kind which depended entirely on steam power as a first mover.

MARSHALL, the same year, at Leeds, began to spin flax by a 28 horse power condensing engine.

PARKES, at Worcester, also applied it to a worsted spinning mill.

DAVISON and HAWKESLEY had begun spinning worsted at Arnold, near Nottingham, by means of a water wheel supplied by Savery's engine —this was given up for Thompson of Ashover's improved atmospheric engine.

1794.

ROBERT STREET, London: "Inflammable vapour force, by means of liquid fire and air, for communicating motion"—Turpentine falling on a plate of hot iron, the vapour which is produced being inflamed under a piston raises it.

1795.

BOLTON and WATT bring an action against a Mr. Bull, who had erected an engine at Oatfield Copper Mine.—Watt's claim was resisted on the plea of an imperfect specification—The jury gave a verdict in favour of the patentees—Points were reserved for the decision of the Judges, which were twice argued before them; the majority gave their opinion in favour of Watt and Bolton.

1796.

VALENTINE CLOSE, Henley: Saving fuel.

JOHN PEPPER, Newcastle: Saving fuel—construction of boiler.

JOHN STRONG, Bingham: Method of constructing the valves.

WILLIAM BATLEY, Manchester: Method of working the engine.

FRANCIS LLOYD, Woolstanton: Construction of furnace.

1797.

AT Sheffield two large condensing engines erected for grinding cutlery.

EDMUND CARTWRIGHT, Middlesex: Condensing engine — metallic piston. Steam-wheel. One of the clauses in the specification was "that instead of water the boiler is to be filled with distillers' wash, to produce the steam with which the engine is to be worked,"—the engine operates as a still and a first mover.

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JOHN GROVER, Chesham: Boiler and furnace.

1798.

WILLIAM RAYLEY, Newbald, Yorkshire: Philosophical furnace and boiler, with an actuating wheel as an appendage.

BOLTON erects a mint at St. Petersburgh.

JAMES SADLER, Oxford: Double cylinders—a combination of Cartwright's and Watt's engines.

JONATHAN HORNBLOWER, Penryn: Steam-wheel, which failed after numerous trials had been made of it, from the difficulty of keeping the packing tight.

GEORGE BLUNDEL, London: Machine for saving fuel.

JOHN DICKSON, Dockhead: Method of constructing.

FRANCISCO RAPOZO, Lisbon: Alterations on cylinder and valves,

J. QUIEROZ, London: Alteration on cylinder: method of forming boiler.

THOMAS ROUNTREE, London: Improvements in furnace and boiler.

1799.

BOLTON and WATT bring an action for piracy against Hornblower and Maberly, for erecting one of his double cylinder-engines, with Watt's improvements—one in 1796, at Meux's Brewery, London. The court gave a decision in favour of the patentees. This action should be considered as far as Bolton and Watt were concerned, rather as a vindication of character than an action for damages—their exclusive privilege expired a few months after the suit was decided in their favour—and it was stated, that but for unfair and invidious comparisons being drawn by their adversaries, and their forbearance being considered as a proof of their own opinion of the weakness of their claim, Bolton and Watt would not have taken this case into court at all.

HUBERT DELAP, Banville: Economical boiler.

JOHN WILKINSON, Castlehead: Boiler—saving fuel.

MARQUIS CHABANNES, London: Improvement on fuel.

MATTHEW MURRAY, Leeds: Boiler—self-regulating damper—horizontal cylinder.

A. G. ECKHARDT, London: Saving fuel.

WILLIAM MURDOCH, Redruth: Casting cylinder—improvements in valves—a steam-wheel.

JAMES BURNS, Glasgow: Saving fuel by alterations on furnace.

JAMES BISHOP, Connecticut: Steam-wheel.

SAMUEL REHE, London: Transmitting the force of any fluid.

T. COOKE, London: Carbofrugalist—mode of applying fire to caldronic implements.

1800.

THE term of twenty-five years granted by Parliament to Watt and Bolton expires—

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Mr. Watt retires from business, and the manufactory of steam-engines at Soho is placed under the direction of Mr. Murdoch of Redruth, who had been Bolton and Watt's agent in Cornwall, and Mr. Southern.

BELLCRANK engine, made at Soho.

PETER DEVEY, London: Improved fuel—same as the burning balls of Liege.

PHINEAS CROWTHER, Newcastle: Crank motion, dispensing with working beam.

JOHN and JAMES ROBERTSON, Glasgow: Furnace for consuming smoke—saving steam by a construction of piston.

1801.

EDMUND CARTWRIGHT, Middlesex: Portable engine—regulating velocity.

A sugar-mill, moved by a steam-engine of eight horse power, constructed at Soho, sent to Demerara—John Rennie, the *Great* in Millwork, designed the mill machinery—it performed excellently.

RICHARD WILCOX, Bristol: Engine and furnace.

WILLIAM HASE, Saxthorpe: improvements on condenser and boiler.

JAMES ANDERSON, Mounie: Saving fuel.

MATTHEW MURRAY, Leeds: Air-pump — valves — parallel motion.

"Hunter and Dickenson, in 1801, tried a steam-boat on the Thames?"

TIMOTHY BRAMAH, Pimlico: Revolving valve.

EARL of STANHOPE: Saving fuel.

GEORGE MEDHURST, London: Converting alternating into circular motion.

GEORGE STRATTON, London: Saving fuel—the method is recommended more to its application in open fires than furnaces.

JAMES GLAZEBROOKE, Colebrooke Dale: Working machines by means of properties of air.

ROBERT YOUNG, Bath: Saving fuel.

WILLIAM SYMINGTON, Kinnard: Steam-boat engine without a working beam—stampers for breaking ice.

JAMES WHITE, an English mechanic then residing in France, receives a medal from Napoleon Bonaparte, for an improved parallel motion.

1802.

JAMES SHARPLESS, Bath: Combinations of the mechanical powers applied to the steam engine.

THOMAS PARKINSON, London: Conveying steam and fluids.

RICHARD TREVITHIC, and ANDREW VIVIAN, Camborne: High pressure steam-engine.

BRYAN HIGGINS, London: Saving fuel—adapted for evaporating.

MATTHEW MURRAY, Leeds: Portable engine—pump and some other improvements.

THOMAS MARTIN, Brentwood: Applying fire by means of certain machinery to heating water.

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THOMAS SAINT, Bristol: Boiler and furnace,

JOSEPH LEWIS, Brinscombe: Furnace.

MATTHEW BILLINGSLEY, London: A very great improvement in the machinery for boring cylinders.

"Some years ago," says Paley, at this time, "a plan was suggested of producing propulsion by reaction in this way; by the force of a steam-engine, a stream of water was to be shot out of the stern of a boat; the impulse of which stream upon the water in the river, was to push the boat itself forward. It is, in truth, the principle by which sky-rockets ascend in the air; and if naturalists are to be believed, it is exactly the device which nature has made use of for the motion of some species of aquatic insects. The larva of the dragon-fly, according to Adams, swims by ejecting water from its tail, and is driven forward by the reaction of water in the pool upon the current issuing in a direction backward from its body."

1804.

RICHARD WILCOX, Bristol: Air-pump—furnace boiler.

JAMES BARBET, Saffron Walden: Economizing fuel.

ARTHUR WOOLFE, London: Two cylinders and high pressure steam; experience has stamped this to be a great improvement.

Mr. Lavaysie mentions, that Mr. Lushington introduced a condensing engine into Trinidad, and estimated its effect as saving two-thirds of the expense of cattle mills.

1805.

JAMES RIDER, Belfast: Lining cylinder—steam regulator.

CHARLES COE, London: Application of heat.

JONATHAN HORNBLOWER, Penryn: Steam-wheel.

WILLIAM EARLE, Liverpool: Working and constructing.

JOHN STEVENS, London: Boiler. Colonel Stevens was an American who has been mentioned in the text, as attempting to introduce steam-boats into America — The boiler was formed by a collection of tubes.

ALEXANDER BRODIE, London: Furnace and boiler.

JAMES M'NAUGHTEN, London: Saving fuel—fire-place.

JAMES BOAZ, Glasgow: Mercury engine.

ARTHUR WOOLFE, London: Open bottomed cylinder—and an excellent contrivance for tightening the packing of piston.

RALPH DODD, London: Saving fuel.

WILLIAM DEVEREL, Blackwall: Furnace and boiler.

SAMUEL MILLER, London: Working and constructing.

JOHN TROTTER, London: Steam-wheel.

ANDREW FLINT, London: Steam-wheel.

1806.

WILLIAM LESTER, London: Steam-wheel.

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J. Bourne, W. Chambers, and C. Gould, Warwick: This patent, in an especial manner, has a relation to the attendants on a steam-engine; it was for roasting meat by steam.

Ralph Dodd, London: Simplification of machinery.

John Lamb, New York: Application of heat.

R. Wilcox, London: Various steam-wheels.

Josias Robins, Liverpool: Furnace.

William Nicholson, London: Application of steam.

Samuel Miller, London: Additions to a former patent.

1807.

Allan Pollock, Glasgow: Saving fuel.

Henry Maudslay, London: Portable engine.

Ralph Dodd, London: Distribution of heat; applicable only to chamber fire-places.

James Bradly, London: Iron for furnace bars.

1808.

Thomas Mead, Hull: Steam-wheel.

Thomas Price, Bilston: Arrangement of parts.

James Linaker, Portsmouth: Steam-boat; drawings of this were given by Mr. Buchanan.

J. Cowden, and J. Partridge, London: Saving of fuel.

Thomas Preston, London: Construction of furnace.

1809.

James Grellier, Aldborough Hatch: Saving of fuel—furnace.

Mark Noble, Battersea: Arrangement of parts.

John Murray and Adam Anderson, Edinburgh: Application of heat.

W. C. English, Twickenham: Saving fuel—heating chambers more especially.

Edward Lane, Stoke on Trent: Arrangement of parts of engine.

J. F. Fesenmeyer, London: Arrangement of parts, and working.

J. F. Archbold, London: Application of heat in apartments and in carriages.

W. Johnson, Blackheath: Heating fluids—evaporation.

Nugent Booker, Dublin: Saving fuel.

Richard Scantlebury, Redruth: Certain improvements.

Samuel Clegg, Manchester: Steam-wheel.

1810.

David Cock, London: Heating fluids.

Arthur Woolfe, London: Constructing—working—saving fuel.

William Docksey, Bristol: Application of heat.

William Clerk, Edinburgh: Regulation of heat.

William Chapman, Newcastle: Steam-wheel.

Richard Witty, Hull; Making — arranging — combining.

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JOHN JUSTICE, Dundee: Application of heat.

STEDMAN ADAM, Connecticut: Certain improvements.

JOHN CRAIGIE, Quebec: Saving fuel.

1811.

JOSEPH MIERS, London: Saving fuel.

RICHARD WITTY, Hull: Additions to former patent.

CHARLES BRODERIP, London: Improvements in construction.

MICHAEL LOGAN, Rotherhithe: Generation of fire.

WILLIAM GOOD, London: Valves.

JOHN TROTTER, London: Steam-wheel.

GEORGE GILPIN, Sheffield: Application of steam.

The proprietors of steam-engines in Cornwall appoint an inspector, to report monthly on the quantity of coals used by each engine.

In August the first average of eight engines, 15,760,000 pounds raised a foot high with one bushel of coal.

In December average of nine engines 17,075,000.

In January 1812, fourteen engines 20,162,000, nearly a saving of a fourth part of all the coal used, from the greater care taken in feeding the furnace.

HENRY JAMES, Birmingham: Steam-boat.

THOMAS DEAKIN, London: Saving fuel.

J. BLENKINSOP, Leeds: Steam-carriage, and improvement in railways. A toothed wheel moved by the engine works into teeth formed in the rail, which prevents the *slipping* that was found to be an objection to Trevithic and Vivian's apparatus. These engines have been in daily use at the Middleton Colliery near Leeds.

1812.

JOHN SUTHERLAND, Liverpool: Boiler—evaporation.

HENRY OSBORN, Bordesly: Manufacture of cylinders.

R. W. FOX and JOEL LEAN, Falmouth: Certain improvements—additional apparatus.

HENRY HIGGINSON, London: Steam-boat.

JEREMIAH STEELE, Liverpool: Application of heat.

WILLIAM ONIONS, Poulton: Steam-wheel.

1813.

ROBERT DUNKIN, Penzance: Saving fuel.

WILLIAM BRUNTON, Butterly Iron Works: Manufacture and arrangements of parts—steam-carriage, the propellers were fashioned to have an action similar to the legs of horses. This patent describes numerous varieties of *feet*. On the whole, notwithstanding its complicated appearance, something of this sort may enable a steam-waggon to pass over acclivities, which to a carriage with wheels only would be inaccessible. Mr. Brunton calls it a "Mechanical Traveller."

ROBERTSON BUCHANAN,

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Glasgow: Steam-boat machinery.

JOHN BARTON, London: Applying the heat which escapes from distillers', dyers', and other furnaces to work an engine—"cock for reversing the steam with two sides cut out, by which the cock requires to be turned only the sixth part of its circumference round; uses a very short piston, which has holes cast or drilled nearly through the piston between the screws, which tighten the cap to put in tallow; this escapes by small holes drilled horizontally into the holes where the tallow is, which keeps the packing always greasy;" this also contains a scheme for boiling in vacuo.

JOHN SUTHERLAND, Liverpool: Furnace.

JOSEPH WHITE, Leeds: Various improvements.

CHARLES BRODERIP, London: Boiler.

1814.

OLIVER EVANS has the term of his patent extended to ten years after this date by the American legislature.

"Mr. J. Carter Hornblower was born of Cornish parents, at Brosely in Shropshire, in 1744. His father wished him to study the law, but consulting his own inclination he was placed under a carpenter; a mutual unsuitability of temper led to an early separation, and Hornblower immediately sought an employment where his mechanical bias would have a wider scope. About 1768 and 1770 he was engaged to erect a steam-engine and some other machinery at Rotterdam, to which place he was a second time invited to superintend similar operations. The improvements which forty years ago were made in the towns of Truro and Tewkesbury, and the erection of the Penitentiary at Northleach, were entirely under his direction. Some of the circumstances which led to the trial in which he, along with his brother Jonathan, were opposed to Bolton and Watt, have already been noticed. To this trial their opponents brought the resolution to succeed, which was aided by their great wealth, and the popularity which success usually inspires—the injunctions which were laid on the engines that the brothers erected proved deeply injurious to others as well as to themselves. J. C. Hornblower afterwards had a patent for a method of glazing calicoes by steam power, a process at that period of great importance to a very extensive branch of English manufactures; a steam-engine and some of the glazing machines were erected, and pieces of calico of the usual length were glazed in two minutes. In this stage of the contrivance it was found, that the preparatory process of waxing the fabric could not be done by hand except at an expense which would overbalance the saving made by the glazing

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machine. Besides the increased velocity which had to be given to the piece of wax, it softened and melted it, and when it was hardened sufficiently to retain its tenacity it lost its lubricating and glazing qualities. Hornblower had succeeded in removing this impediment, and was in the very act of erecting the necessary supplemental mechanism, when the individual, a sanguine, liberal, but obstinate man, who had purchased the patent right, and who imagined at the first that the waxing was a process of much easier accomplishment than the glazing, wearied by the expense and repeated disappointment, would proceed no further; he locked up the premises containing all the machinery, with a resolution not to open them during the term of the lease: nor could the urgent entreaties of his friends —nor the representations of the inventor, induce him to alter his determination; the business was settled by arbitration. At the termination of the lease the steam-engine was sold by auction, and the millwork broken up; but the inventor was not permitted to profit by the invention.

"A German gentleman who knew his talents and experience as an engineer, engaged him in 1810, to design and erect an extensive malting and brewing establishment in Sweden. The services he rendered in this employment were so highly valued, that the remuneration which had been allowed for his superintendence was generously continued to be paid to him after his labours for his patron had ceased. He returned to England in 1813, and died in London in 1814.

"Mr. Hornblower was one of those of whom, without looking to a higher source, it might be said, that Disappointment

—'marked him for her own.'

Destitute of capital, and with the constantly increasing wants of a large family to supply, he could only exert his talents under the control of others. In this unpropitious situation he was alternately the sport of hope and disappointment; and in his efforts to emerge from that condition in which

'Where penury is felt
The mind is chained,'

it may have been that his integrity was not accompanied by that flexibility of disposition which the world exacts from those it permits to be in the 'way to rise.' He was fortunate, however, in acquiring the confidence and regard of individuals of high character and talent with whom he had been connected in his professional career. His exemplary tenderness, affection, and self-denial, in his domestic relations should above all be recorded to his honour."
—*Memoir by A. Hillhouse.*

W. A. Noble, London: Arrangement.

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"A steam-boat, 40 tons burthen, put in motion in the canal near Limehouse, (the Lord Mayor on board;) it ran a mile and returned in sixteen minutes."

JOHN RASTRICK, Bridgenorth: Certain improvements.

R. W. KING, London: Boiling water.

THOMAS TUDAL, York: steam-carriages.

JOHN SLATER, Birmingham: Boiler.

Mr. KONIG, a Saxon printer, succeeds in constructing a printing press, to be moved by a steam-engine. The *Times* newspaper, of Monday, the 28th November, 1814, was the first publication printed in this way. Konig was associated with Mr. Bensley, senior, and Mr. Richard Taylor. Konig's first scheme went no farther than to increase the speed of the common press.

1815.

R. DODD, and G. STEPHENSON, Killingworth: Steam-carriage — the resistance is produced by the wheel on the rail as in Trevithic and Vivian's locomotive; a pin upon one of the spokes of the wheel had the lower end of the connecting rod fastened to it by a ball-and-socket joint — the other end is connected to the cross beam moved by the piston. The pin upon the spokes converted the reciprocating motion of the piston into a rotary one; the carriage was placed on six wheels, which were attached to each other by an endless chain—spiked wheels working into the links communicated motion to the series.

WILLIAM LOSH, Northumberland: Furnace.

HENRY HOULDSWORTH, Glasgow: Discharging the condensed steam; permitting air to enter a series of pipes to prevent the strain from atmospheric pressure. The expansion and contraction of the pipes opening or shutting a valve.

MATTHEW BILLINGSLEY, Bradford: Improvements.

RICHARD TREVITHIC, Camborne: Making piston air-tight—rotative engine—impelling a steam waggon or boat.

WILLIAM MOULT, London: Furnace.

JOHN CUTLER, London: Supplying fire with fuel. The fuel was made to rise from the bottom of the grate, so that all the gas, as it exhaled from the fresh portion of fuel, was ignited in passing through the burning coals which lay uppermost. This ingenious and elegant contrivance involved its author in a law-suit, in which the *quibbles* of his mercenary rivals in trade prevailed over the fairest claim to the protection of a patent.

W. and M. BEVAN, Glamorgan: Furnace.

MARQUIS DE CHABANNES. A method of heating air. The Marquis applied the scheme to boilers.

1816.

J. DAWES, Bromwich: trans-

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mitting the alternating impulse of a steam piston.

J. F. Muntz, Birmingham: Destroying smoke — saving products—furnace.

Bryan Donkin, Surrey: Boiling water.

Alexander Rogers, Halifax: Saving fuel — setting boilers.

Philip Taylor, Bromley: Application of heat.

William Stenson, Coleford: Improved engine.

Robert Stirling, Edinburgh: Saving fuel.

John Barton, London: An excellent metallic piston —an improvement on Cartwright's—wedges acted on by springs, keeping the outer series of pieces, or the packing pressed to the face of the cylinder.

George Bodley, Exeter: Certain improvements.

Joseph Turner, Layton: Steam wheel.

John Neville, London: Generating and applying steam.

Joseph Gregson, London: Supplying fuel.

William Losh, Newcastle: Furnace.

1817.

W. A. Osborne, Bordesley: Boring cylinder.

George Mainwaring, Lambeth: Certain improvements.

John Oldham, Dublin: Steam boats.

George Stratton, London: Saving fuel.

Moses Poole, London: Certain improvements.

1818.

Lord Cochrane, and A. Galloway, London: Machine for consuming smoke.

William Moult, London: Certain improvements.

Alexander Haliburton: Wigan: Furnace.

John Scott, Penge: Steamboat.

Philip Taylor, Bromley: Application of heat.

J. Munro, London, and Barnabas Langton, New-York: Certain improvements.

Joshua Routledge, Bolton le Moor: Steam-wheel.

James Ikin, Christchurch: Hollow furnace bars.

William Church, London: Certain improvements.

William Johnston, London: Destroying smoke—furnace.

Marquis de Chabannes, London: Boiler of tubes.

Jones and Plimley, Birmingham: Certain improvements.

Henry Creighton, Glasgow: regulating admission of steam into pipes.

John Malam, London: Steam-wheels.

Sir William Congreve, London: Steam-wheel.

James Fraser, London: Junction of tunnels in boiler.

Richard Wright, London: Construction — subsequent employment of steam.

John Seaward, London: Generating steam.

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WILLIAM BRUNTON, Birmingham: An ingenious revolving furnace, which feeds itself with fuel, and is regulated with great precision; it is by far the best mechanism for this purpose which has yet been produced.

Engravings of its details and some particulars of its effects will be given in *Stuart's Practical Treatise on the Construction of Steam-Engines.*

GEORGE KELLEY, Briggan: Constructing.

JOHN PONTEFEX, London: An elegant, effective, portable and self-regulating engine, on the principle of Savery's machine.

1820.

JOHN OLDHAM, Dublin: Additions to former patent.

JOHN WAKEFIELD, Manchester: Furnace, and method of supplying it with fuel.

October 18th.—A steam-brig sailed from port L'Orient, which arrived at Senegal in sixteen days.

WILLIAM BRUNTON, Birmingham: Additions to a former patent.

WILLIAM CARTER, Middlesex: Steam-wheel—an improvement on Hornblower's first scheme, in that part of the mechanism which made the pistons become alternately the abutment valves. Carter's clamps were portions of a spiral curve, formed so as to slide in its box, when the piston attached to it received its direct motion—but to press against its sides when the piston, or diaphragm was impelled in the contrary direction—a slight turning of the lever relieved the pressure, and it then moved freely as before.

JOHN BARTON, London: Engines and boilers for steam-boats.

JOHN HAGUE, London: Constructing.

JOSEPH PARKES, Warwick: Consuming smoke.

JOB RIDER, Belfast: Steam-wheel. A figure of this is given in the plate marked VAUGHAN, &c.; it will be recognised as a variety of Bramah's. Rider is said to have erected several large engines of this kind—their performance has not been stated.

JOHN MOORE, Dublin: Steam-wheel.

WILLIAM PRITCHARD, Leeds: Furnace.

1821.

WILLIAM ALDERSLEY, Middlesex: Substitute for the crank.

JOHN BATES, Bradford: Supplying fuel to furnace.

THOMAS MASTERMAN, London: Steam-wheel.

ROBERT DELAP, Belfast: Among other matters in this patent is a steam-wheel of the same kind as Cooke's.

ROBERT STEIN, London: Certain improvements.

JONATHAN DICKSON, London: Transmitting heat.

HENRY PENNECK, Pen-

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zance: Furnace lessening consumption of fuel.

PETER DEVEY, London: Preparing fuel; a sort of burning balls, by mixing coals and other substances together. The fuel, as to appearance, for many purposes is better than crude coal—its economy is doubtful.

HENRY BROWN, Derby: Furnace—consuming smoke.

PHILIPS LONDON, London: Furnace.

AARON MANBY, Horsley: Manufacture of details.

THOMAS BENNETT, Bewdley: Certain improvements.

FRANCIS A. EGELLS, London: Improvement in details.

SIR WILLIAM CONGREVE, London: Addition to former patent.

CHARLES BRODERIP, London: Construction.

NEIL ARNOT, London: Furnace and boiler.

JULIUS GRIFFITH, London: Steam-carriage; this is the first scheme in which the engine is placed on springs—a machine it was understood was constructing by Bramah at Pimlico; we know not if it has ever been exhibited.

1822.

RICHARD ORMROD, Manchester: Construction of boiler.

G. A. PALMER, London: Furnace for consuming smoke.

GEORGE STEPHENSON, Benton: Certain improvements.

ALEXANDER CLARK, Fife: Boiler and condenser.

M. J. BRUNEL, Chelsea: Placing cylinder inclined to the horizon.

JOSEPH SMITH, Sheffield: Boiler.

JOHN STANLEY, Manchester: Supplying fuel to furnaces.

J. and J. BINNS, London: Boiler.

J. LEACH, London: Steam-wheel.

JACOB PERKINS, London: Boiler.

BAINBRIDGE and THAYER, London: Rotatory engine.

1823.

JAMES NEVILLE, London: Furnace and boiler.

WILLIAM JOHNSON, Great Totham: Furnace and boiler.

ROBERT COPELAND, London: New combinations for gaining power.

NATHANIEL PATRIDGE, Stroud: Setting boilers.

H. H. PRICE, Neath Abbey: Machinery for steam-boats.

WILLIAM JESSOP, Butterley: An ingenious metallic piston—"A spiral spring coiled round the rubbing part of the piston between the upper and under plates expands outwards as the piston screws are tightened; it has been used in many cases with good effect."

JACOB PERKINS, London: Boiler.

THOMAS PEEL, Manchester: Steam-wheel.

The Diana steam-boat, built in Mr. Kyd's yard, at Kidderpore near Calcutta, launched on the 12th of July; and on the same day she made her

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first voyage on the Ganges between Calcutta and Chinsurah, in six hours and a half. This was the first appearance of these boats in the East.

JACOB PERKINS, London: Additions to former patent.

FISHER and HORTON, West Bromwich: Circular boiler, in which the steam, after it rises into a space over the water, is conducted downwards into a reservoir, or chamber placed in the water, and thence it is conveyed to the engine; no heat can, therefore, be lost by radiation from the steam-chamber. (?)

WILLIAM JUKES, London: Regulating the supply of water admitted into boiler.

BOWER and BLAND, Leeds: Engine without air-pump.

WILLIAM WIGSTON, Derby: Certain improvements.

ROBERT HIGGIN, Norwich: Consuming smoke.

JAMES LARREY, Battersea: Saving fuel.

JAMES CHRISTIE, and W. HARPER, London: Mix three parts of stone coal, culm, or Kilkenny coal, with one part of Wallsend, or any other bituminous coal. When there is "a good draught," and the furnace bars an inch wide and half an inch apart, "this will give out much heat." Londoners, for generations, have considered this *patent practice* a very great nuisance. The invention would have been infinitely more popular had it been directed to prevent this *patent* combination, and to supply pure *coals*, and allow every fire-feeder to mix them to his own taste.

JACOB PERKINS, London: Furnace—boiler.

SAMUEL BROWN, London: Gas-engine.

WILLIAM FURNIVAL, Droitwich: Boiler.

JAMES SMITH, Droitwich: Boiler.

1824.

MOSES ISAACS, London: Improvements in details.

MAURICE DE JOUGH, Warrington: Combining coke oven with an engine boiler.

SAMUEL HALL, Basford: Decomposing the *steam* in a greater or lesser degree in its passage from the boiler to the cylinder, under a *pressure superior* to that of the atmosphere. The furnaces are made air tight, and the vapour which rises from the water enters the furnace, and this mixture of gases and vapour is conducted into the cylinder.

GEORGE VAUGHAN, Sheffield: Double atmospheric engine.

J. T. PAUL, London: Boiler—a long copper pipe of small diameter coiled round the inside of the furnace, producing a conical figure, within which the fuel is placed; a small forcing pump injects the water at one end, which escapes in the form of steam at the other: 150 feet of a pipe 3-16th of an inch internal diameter, sufficient for a two horse power; the pipes may be coated with clay.

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W. H. JAMES, Birmingham: Steam-carriage.

SIR GEORGE CAYLEY, York: Locomotive apparatus.

JOHN M'CURDY, London: Tube boiler. "One of these tubes 11 feet 6 inches long, 6 inches diameter at the larger end, and 3 inches at the smaller, produced as much steam as a boiler containing 150 cubic feet." This tube is placed in a furnace, and water is forced into it by a forcing pump through a small pipe called the injection barrel; "each chamber with about a cubic inch of water, injected at every stroke of the pump, will supply an engine having a four horse power."

PHILIP TAYLOR, London: Horizontal cylinder—contrivance to stiffen the piston rod, and lessen the tendency of the gravitating action of the piston to alter the form of the cyinder.

WILLIAM FOREMAN, Bath: Steam-wheel.

PIERRE ALEGRE, London: Boiler.

"The Robert Fulton, steam-ship, completely armed, and filled with military stores, and navigated by 30 American seamen, sailed from Boston, in September, for Greece; she was a present from the freemen of America to the freemen of the Levant."

JOHN MOORE, Bristol: Construction.

DAVID GORDON, London: Steam-carriage.

"Mr. Gordon's application of legs and feet differs from Mr. Brunton's (in 1813), inasmuch as Mr. Brunton uses a *pair of feet* only with their leg appendages—these have a reciprocating parallel motion. Mr. Gordon's feet, or rather his carriage feet, are six in number, forming a continuous series by their being attached to revolving cranks.

"The feet are placed in the fore part of the carriage, and raised by a light six throw crank; by its revolution they are forced out against the ground in the manner of the hind legs of a horse—the rods or 'leg bones' are formed hollow (as in nature); these iron-rods are filled with wood, (instead of marrow,) to combine lightness with strength; the legs are attached to what may be considered substitutes for horses' feet, although their form being segments of circles is very different." "They press against the ground by a rolling sort of motion, causing a sufficient adhesion to the surface without either slipping or digging it up, and adapt themselves to any slight turn of the carriage. The under part of these feet (query soles) is formed of cork, short hair, whalebone, or any other stiff and elastic material, placed endways and supported by iron teeth, which would take effect in the event of the packing failing. In countries where sledges are used for travelling over snow, the machine may be placed on *skates*, and the feet shod with suitable iron teeth." Snow shoes

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in this case, we doubt not, would give all the resistance wanted. The entire mechanism is one of the best that has yet been produced.

SAMUEL BROWN, Commander in the Royal Navy: Steam-boat machinery.

MAUDSLAY and FIELD, London: Changing continually the water used in the boilers of steam-boat-engines, and thus preventing the deposition of salt.

1825.

WILLIAM FRANKLIN, London: Self-acting feeder for high pressure boilers.

DR. A. TILLOCH, London: A steam-wheel. The Doctor's death happened before he had completed a description of this scheme—it was similar to Amonton's wheel.

BURSTALL and HILL, London: Steam-carriage.

WILLIAM GRISENTHWAITE, Notts: Air-engine.

Steam-engines in operation, at Glasgow, as stated by Mr. Cleland:

	Horse Power.
Spinning Cotton	893
Weaving	665
Raising	262
Bleaching, dyeing, printing and discharging	206
Calendering	154
Grain grinding	153
Founding	124
Distilling	119
Engine making	62
Chemical operations	39
Machine making	37
Carried Forward	2714

	Horse Power.
Brought Forward	2714
Snuff making	22
Fine Brick making	19
Sugar refining	18
Lamp-black making	18
Twisting yarn	18
Smith work	18
Grinding drugs	14
Coach making	12
Glass grinding	12
Grinding malt and pumping worts	20
Grinding colours	14
Veneer sawing	10
Tambouring	10
Cutting wood	18
Wool carding	8
Pottery	7
Singeing muslins	6
Gas	4
Coppersmith	4
Tanning	4
176 Engines exerting	2970
58 Engines at coal mines	1411
7 Engines at stone quarries	89
68 Engines in steam-boats	1926
Clyde Iron Work	60

Total 310 engines having 6406 horse powers; the average power of each engine about 20·6 horse power.

This is exclusive of the engines in nearly all the extensive cotton works in the district around Glasgow.

"The difference of cost between the price of coals consumed by an engine and the keep of horses must ever vary with circumstances—a heavy horse will consume 15 pounds avoirdupois of oats, and 14

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pounds avoirdupois of hay a day. An engine of 30 horse power, working 10 hours per day in a mill, will consume, on an average, in summer and winter, about 4 tons of coal dross."

NEIL SNODGRASS receives a premium from the magistrates of Glasgow for his improved piston packing.

LORD COCHRANE, London: A method of propelling ships.

J. SUNDERLAND, Blackheath: Combination of fuel—one part of tar, one part of saw-dust, and one part of clay, mixed *secundum artem*, and spread out for three months—the mass may be afterwards made into boluses, and "used as wanted;" a dozen "will move" a four-horse-power.

J. C. RADDATZ, and E. ALBAN, Boiler.

W. H. JAMES, Birmingham: Boiler.

GEORGE CHAPMAN, of Whitby, proposes a scheme to prevent the air which is to assist in the combustion of the fuel from getting into the furnace in its cold state, by casting the grate bars hollow, which open into two boxes: the front box has a register; the back box opens directly under the fire bridge, which is made double; the air passing through the bars and tubes is heated before it issues from the back box to mingle with the vapour which is to be ignited.

THOMSON and BURR, Chelsea: Boiler. Four cylindrical vessels, equidistant from each other, placed over the fire; their pivots are placed outside of the furnace, a cog-wheel on each of these axles is made to revolve by a fifth wheel, placed in the centre between the four; water is supplied to the vessels by a forcing pump; as the vessels revolve, every part of the surface of each is submitted to the action of the furnace.

SAMUEL BROWN, London: Additions to former patent.

M. J. BRUNEL, London: Liquid gas engine.

J. A. TESSIER, London: Construction.

16th August—The *Enterprise* steam-packet leaves Falmouth for the East Indies—arrives at the Cape of Good Hope on the 13th of October.

"Signal," says the *Cape-town Gazette*, "having been made soon after day light, that she was standing into Table Bay, a vast concourse of people assembled on Green-point, and at other places from whence a view of the bay can be obtained. The wind being light from the southward the vessel steamed to her anchorage in magnificent style, under a salute from the castle. The greatest distance run in any twenty-four hours was one hundred and ninety miles by sailing—by steaming one hundred and sixty miles."

THOMAS HOWARD, London: Alcoholic vapour engine.

JOSIAH EASTEN, Bradford: Steam-carriage and rail-roads.

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GOLDSWORTHY GURNEY, London. Mr. Gurney trusts to wheels for propelling his carriage along level roads. In *up-hill work* he calls in the aid of *legs and feet*, which have been unkindly denominated *crutches*.

JOHN GILMAN, and W. SOWERBY, London: Introducing vapour under the ignited fuel in a furnace—to decompose it, and produce heat by the inflammation of its hydrogen!!

L. W. WRIGHT, London: Steam-wheel.

F. HALLIDAY, Ham: Rotatory engine.

JOSEPH EVE, Liverpool: Steam-wheels.

J. M'CURDY, London: Generating steam.

JOHN REEDHEAD, Heworth: Machinery for steam-boats.

JOHN MOORE, Bristol: Boiler—vertical tubes communicating with a steam-chamber—the tubes are arranged in a circular row, within which the fire is placed.

J. SURREY, London: Application of heat to boilers.

DAVID GORDON, London: Steam-boat—encloses the paddle wheels in a case furnished with a sluice for regulating the supply of water; the water enters the case entirely below the water line; a vessel or tank suspended over weather side of boat, at a considerable distance from it, to keep the boat on an even keel; surrounding a boat at the height of the gunwale with a chevaux de frise, set with pikes like a hedge-hog's back to break the force of the waves rolling on board of a vessel; or a chevaux de frise may be made to float on the water to protect a ship when at anchor, when lying to, or scudding through a heavy sea.

J. BLOOMFIELD, and J. LUCOCK, Birmingham: Propeling vessels.

1826.

JOHN POOLE, Sheffield: Boiler.—A series of flat vessels placed one over the other; communicating with each other by means of short pipes.

A. A. LORENT, London: Applying steam.

JAMES NEVILLE, London: Generating steam.

BENNET WOODCROFT, Manchester: Paddles for steam-boats.

SAMUEL BROWN, London: Additions to former patents—propelling boats.

HENRY HIGGINSON, London: Steam-boat.

MARQUIS DE COMBIS, London: Rotatory engine.

ROBERT MEIKELAM, London: Inflammation of gas in a closed cylinder to raise a piston—producing vapour from alcohol within the cylinder, by means of a piston heated by a *current* of oil; a small model on this plan acted with considerable effect and precision. But Mr. Meikelam found, in the slowness with which the oil transmitted heat, a difficulty in keeping the surfaces which had gene

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rated the vapour at the required temperature.

WILLIAM ROBINSON, London: Steam-boat—the apparatus is moveable, and may be attached either to the stern or stem of the boat.

COUNT EUGENE DE ROSEN, London: For communicating power.

T. B. WILKS, Tunbridge-Hall: Generating steam.

JAMES YANDAL, London: Method of condensing vapour by opposite currents—he applies it in distilling; and it has been thought applicable to the condenser of a steam-engine.

BURSTALL and HILL, Leith: Additions to former patent for steam-carriage.

ELIJAH GALLOWAY, London: Steam-wheel.

JOHN COSTIGIN, Louth: Cylinder placed horizontal—a method of preventing the effects of gravity in destroying the figure of the cylinder and piston — boiler of tubes — he places boilers far apart from the cylinders — and recommends four cylinders.

COSTIGIN revives the method of *guiding* and impelling ships by a stream of water ejected from the stern—*by which a ship may be placed in any position even after her masts and rudder have been lost.* A small horizontal cylinder works two force pumps —it differs little from Linaker's scheme; all the machinery is placed below the water line.

W. CHURCH, Birmingham: Improvements in the method of casting cylinders.

He exhausts the air from the moulds by an air-pump, and forces the fluid metal from an air-tight reservoir beneath into the moulds; air-holes, honeycombs, and other flaws are prevented, by this process, from being formed in the casting.

1827.

JAMES FRAZER, London: Boiler.

ROBERT COPELAND, London: Addition to former patent.

ROBERT BARLOW, Chelsea: Substitute for crank.

JAMES and ROBERT STIRLING, Glasgow; Air-engines.

JOHN WHITE, Southampton: Piston and valves.

W. PARKINSON, Barton: Constructing and working an engine for communicating power and motion.

THOMAS PECK, London: Revolving steam-engine.

PETER BUST, Limehouse: Improved engine.

JOHN OLDHAM, Dublin: Steam-boat machinery wheels.

WILLIAM STRATTON, London: Heating air by steam.

SIR W. CONGREVE, London: New motive power.

FOX and LEAN, Falmouth: Various improvements.

JACOB PERKINS, London: Additions to former patents.

J. S. HOLLAND, London: Steam-carriage machinery.

P. STEINSTREET, London: Steam-boat machinery.

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JOHN L. STEPHENS, Plymouth: Steam-boat machinery.

A. M. SKENE, London: Steam-boat machinery.

1828.

GOLDSWORTHY GURNEY, London: Steam-carriage.

J. GILBERTSON, Hertford: Smoke-consuming furnace.

JOHN EVANS, Wallingford: Certain improvements.

J. T. BEALE, London: Communicating heat.

J. NEVILLE, London: Steam-carriage.

GEORGE JACKSON, Dublin: Steam-boat machinery.

FREDERIC ADAMS, Essex: Steam-carriage.

W. HALE, Colchester: Steam-boat machinery.

FINIS.

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Preparing for Publication by the same Author.

A

PRACTICAL TREATISE

ON THE

CONSTRUCTION

OF

STEAM-ENGINES.

This will contain many rules for proportioning their parts, and Tables for facilitating their application in practice.

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It will be printed to correspond in size with the "Anecdotes of Steam-Engines," and will form a useful companion to these two volumes.

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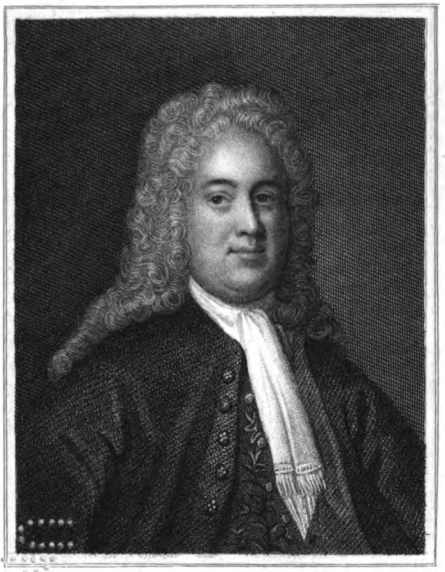

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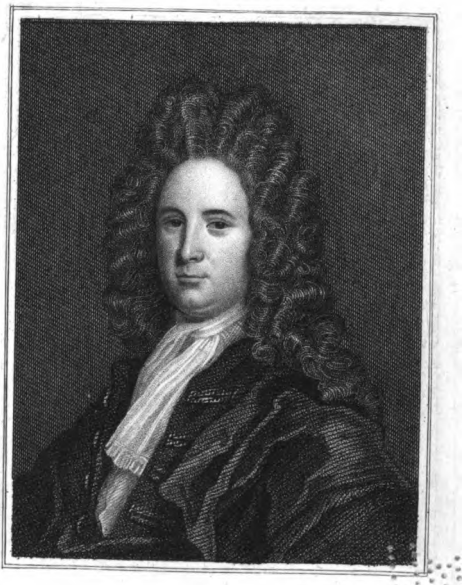

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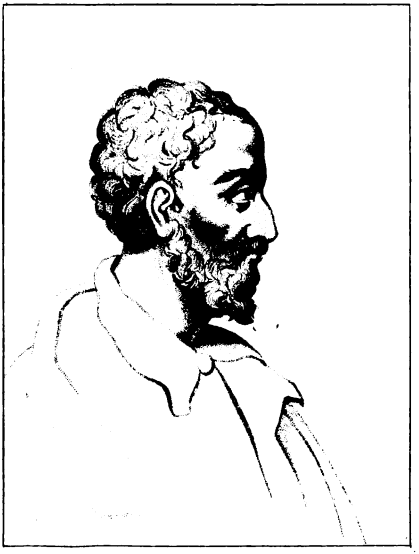

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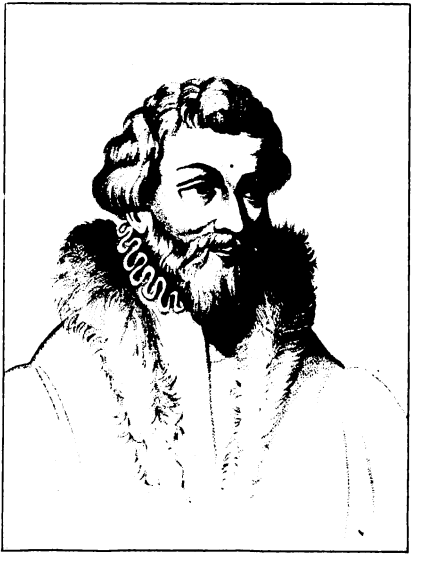

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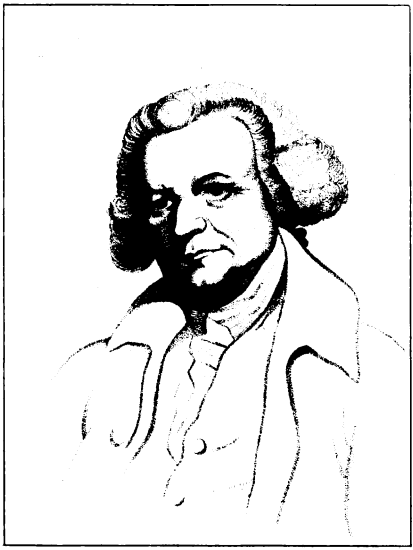

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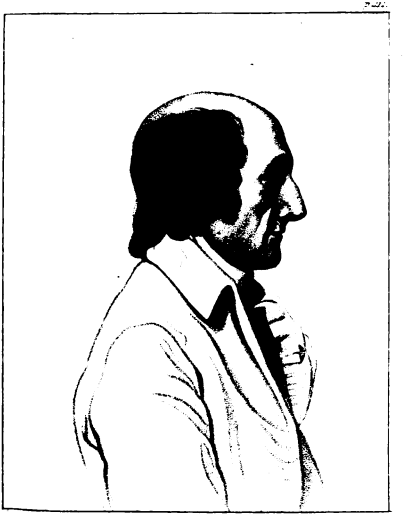

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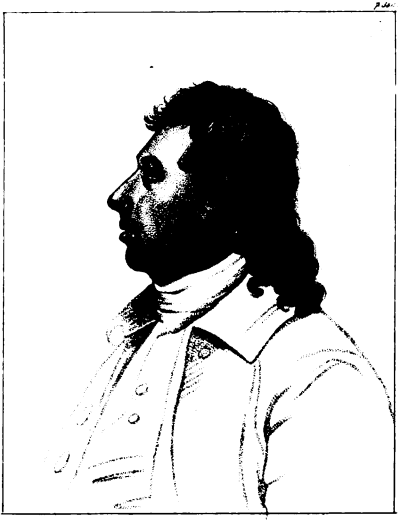

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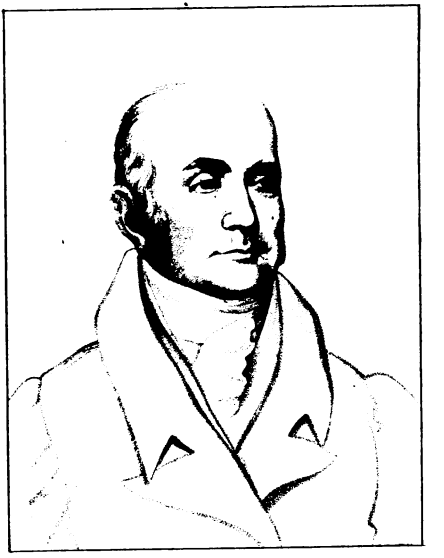

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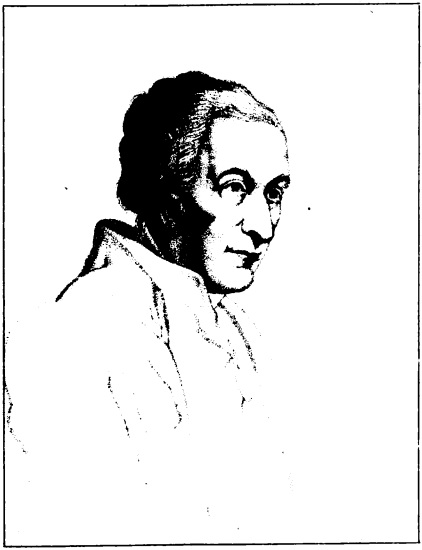

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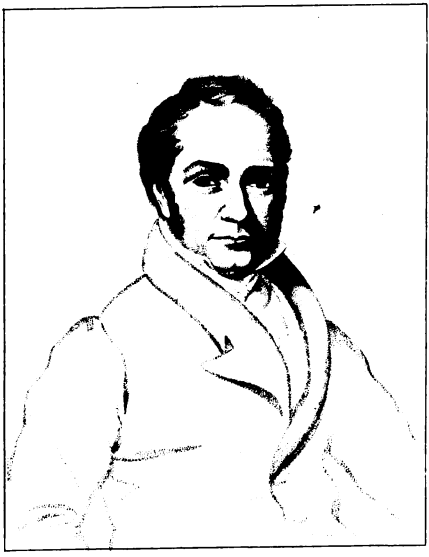

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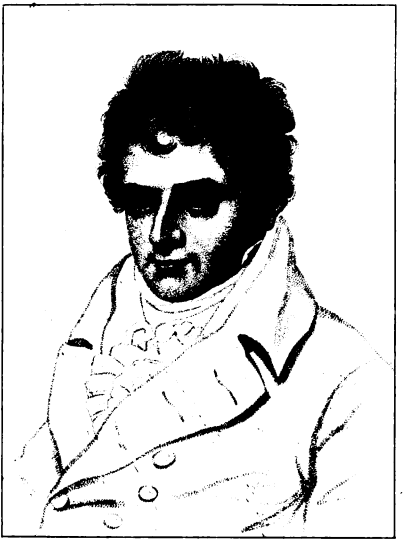

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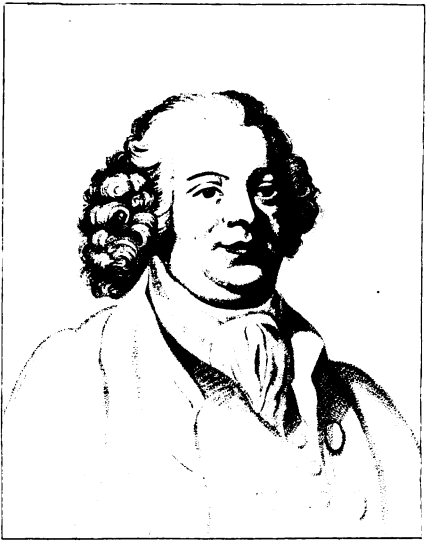

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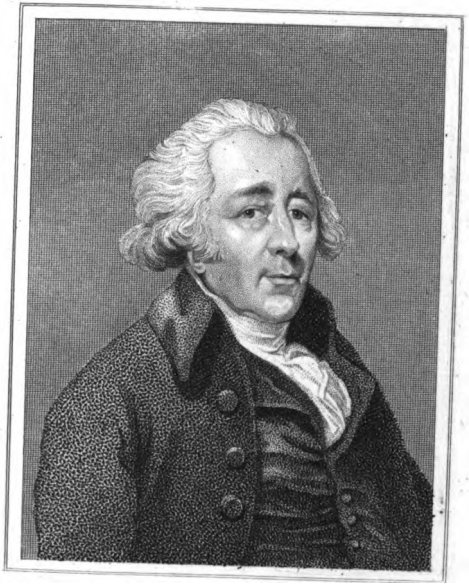

BOLTON

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Guilliaume
Leibnitz

votre très humble et très
obéissant serviteur
Leibnitz

Hanover ce 21 d. Xbre n. s.

most obedient servant
D. Papin

ce 18 e Decemb. 1708

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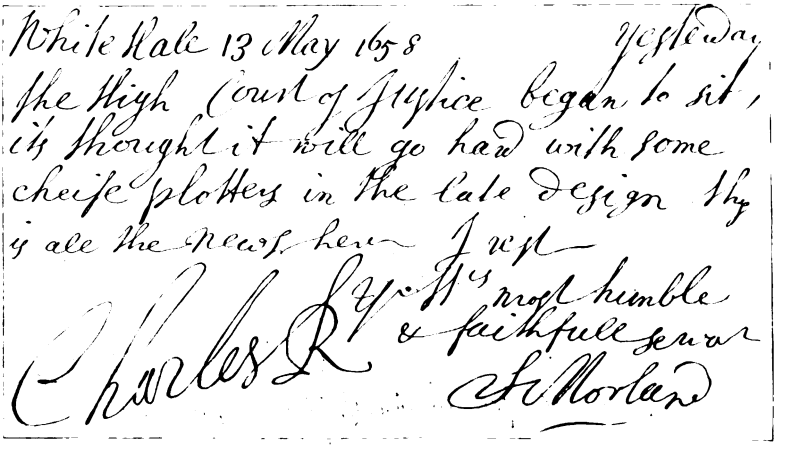
FAC-SIMILES



White Hall 13 May 1658 Yesterday
the High Court of Justice began to sit,
it's thought it will go hard with some
cheife plotters in the late design thy
is all the news here I rest
Charles R Yr Ms most humble
& faithfull servt
H Morland

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I am glad S^r Christopher & M^rs Wren
like the house & hope they like the
price also

Your most humble Servant

Thank God Js Newton

William Gresham Coll June 20. 1691.

Your most faithfull humble
Serv^t Rob Hooke.

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Hen Beighton

Your Most Obliged
Serv^t
R Bradley

Your most humble
and obedient Servant
I T Desaguliers

your humble Sevt
Stephen Hales

your most obliged
humble Sevt
J Smeaton

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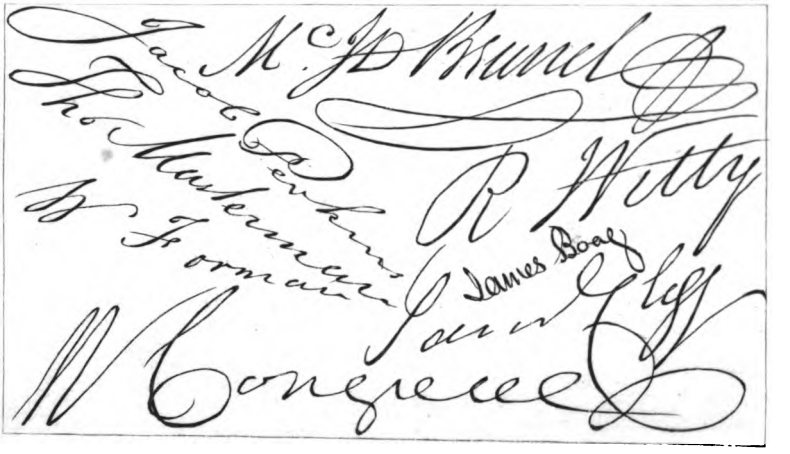

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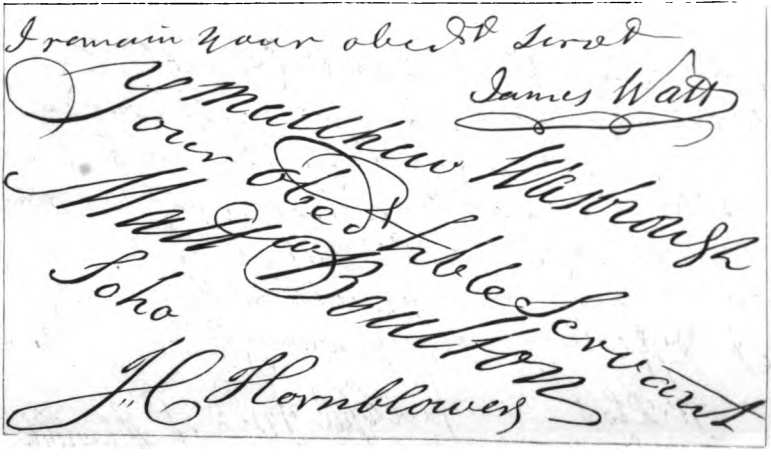

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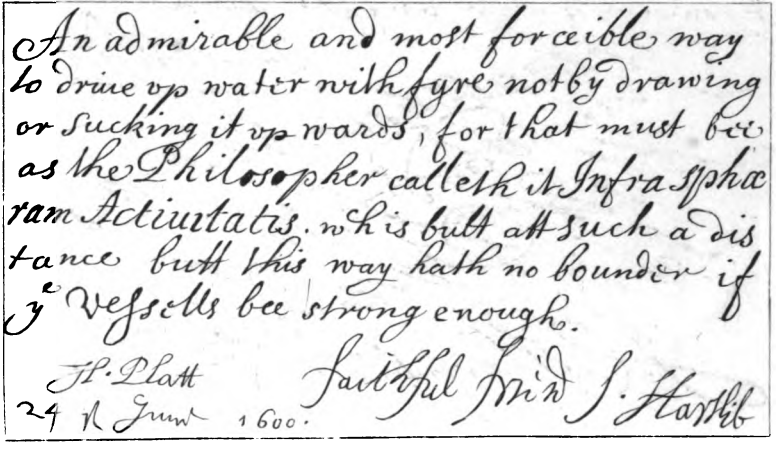

An admirable and most forceible way to driue vp water with fyre not by drawing or sucking it vp wards, for that must bee as the Philosopher calleth it Infra sphæram Actiuitatis. wch is butt att such a distance butt this way hath no bounder if ye Vessells bee strong enough.

Sr. Platt
24 th June 1600.

Faithfull Frd S. Hartlib

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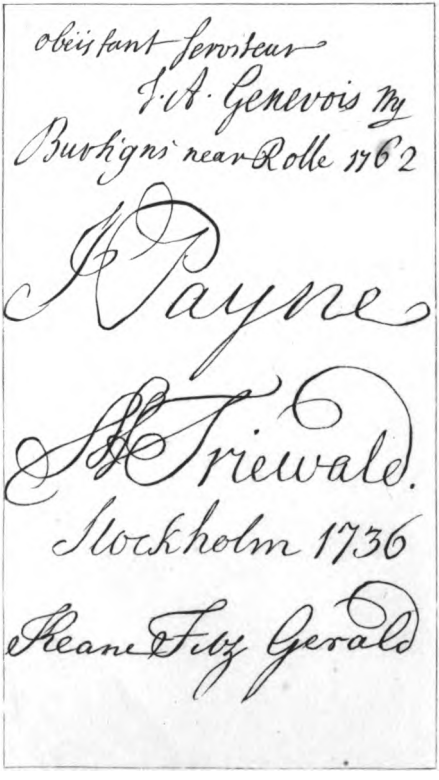

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